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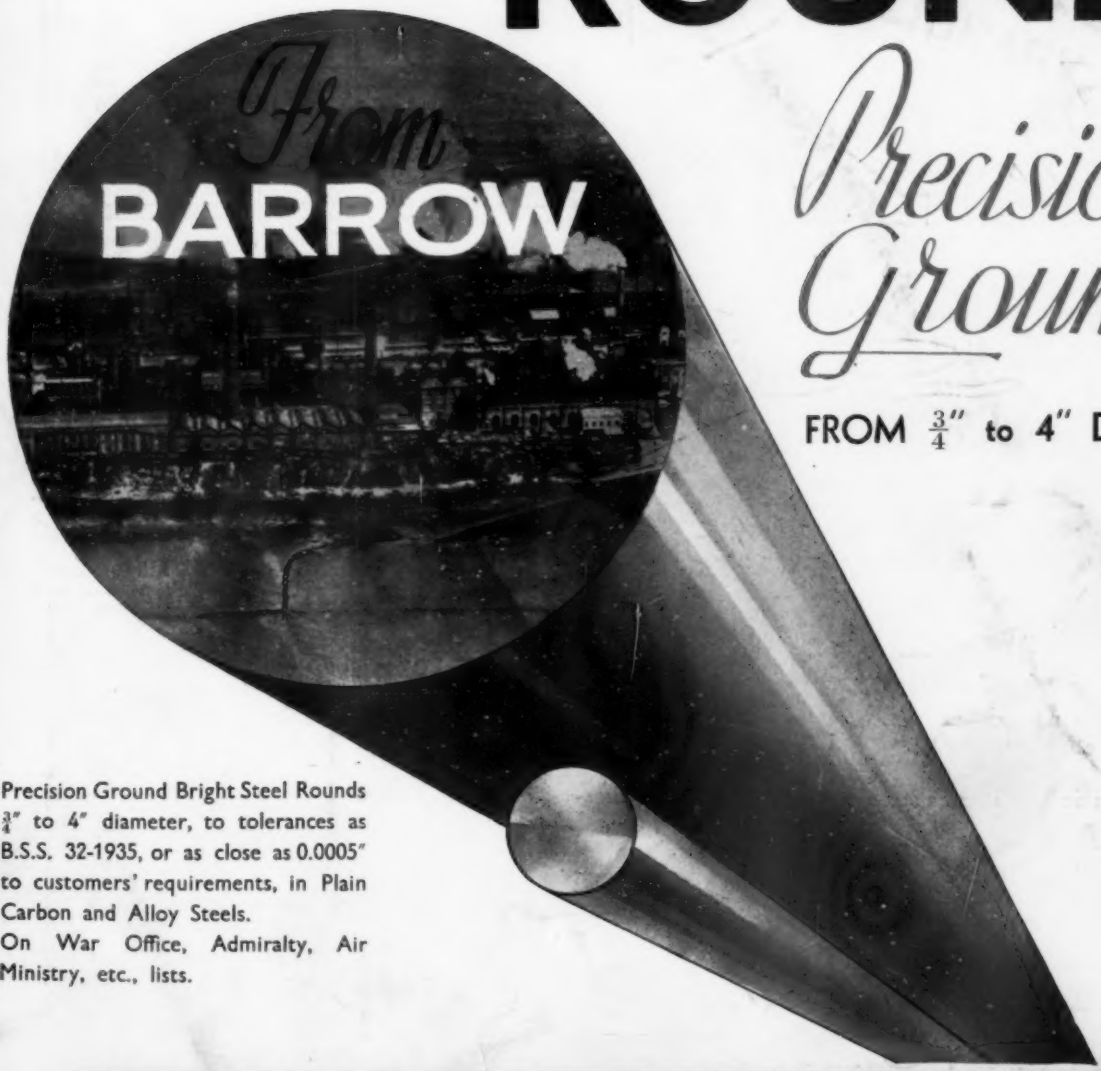

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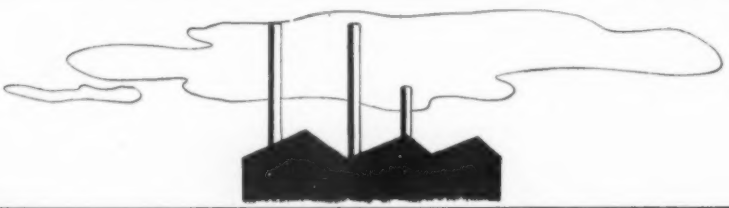

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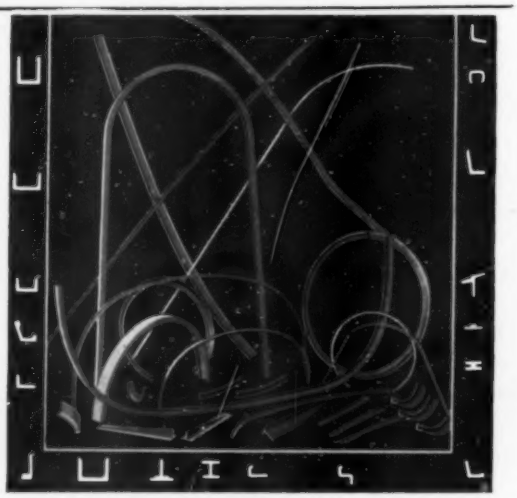

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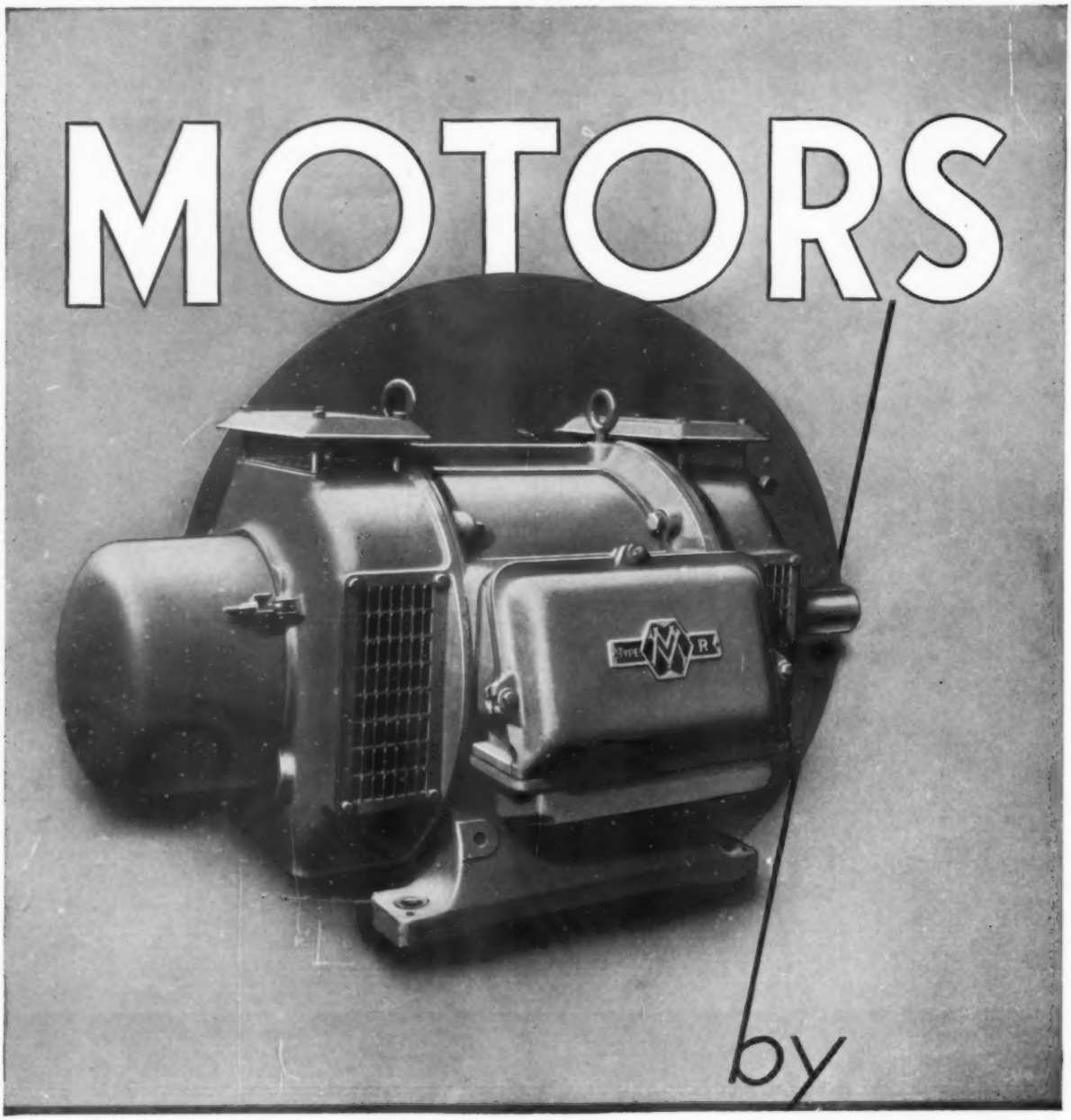

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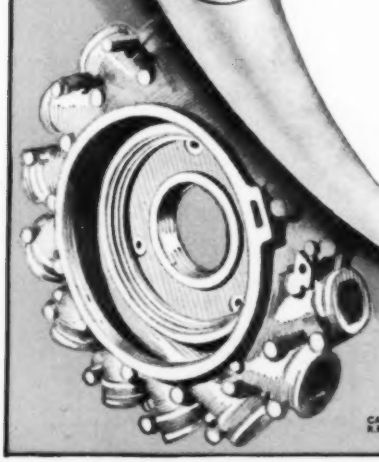

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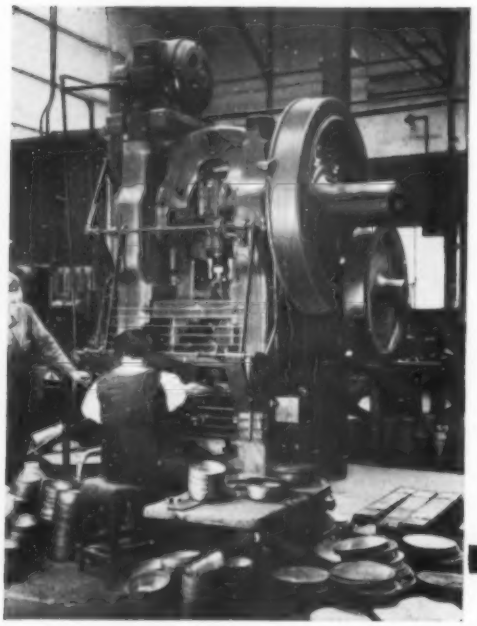

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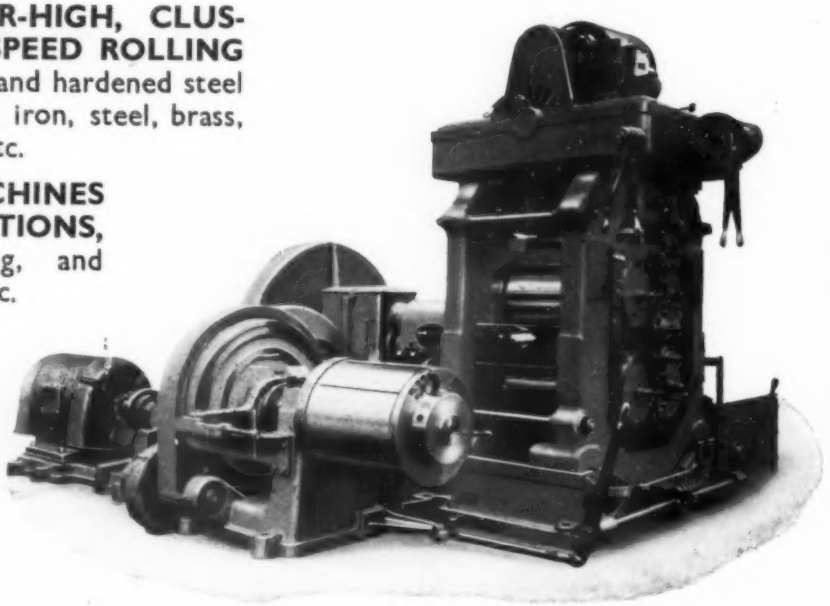

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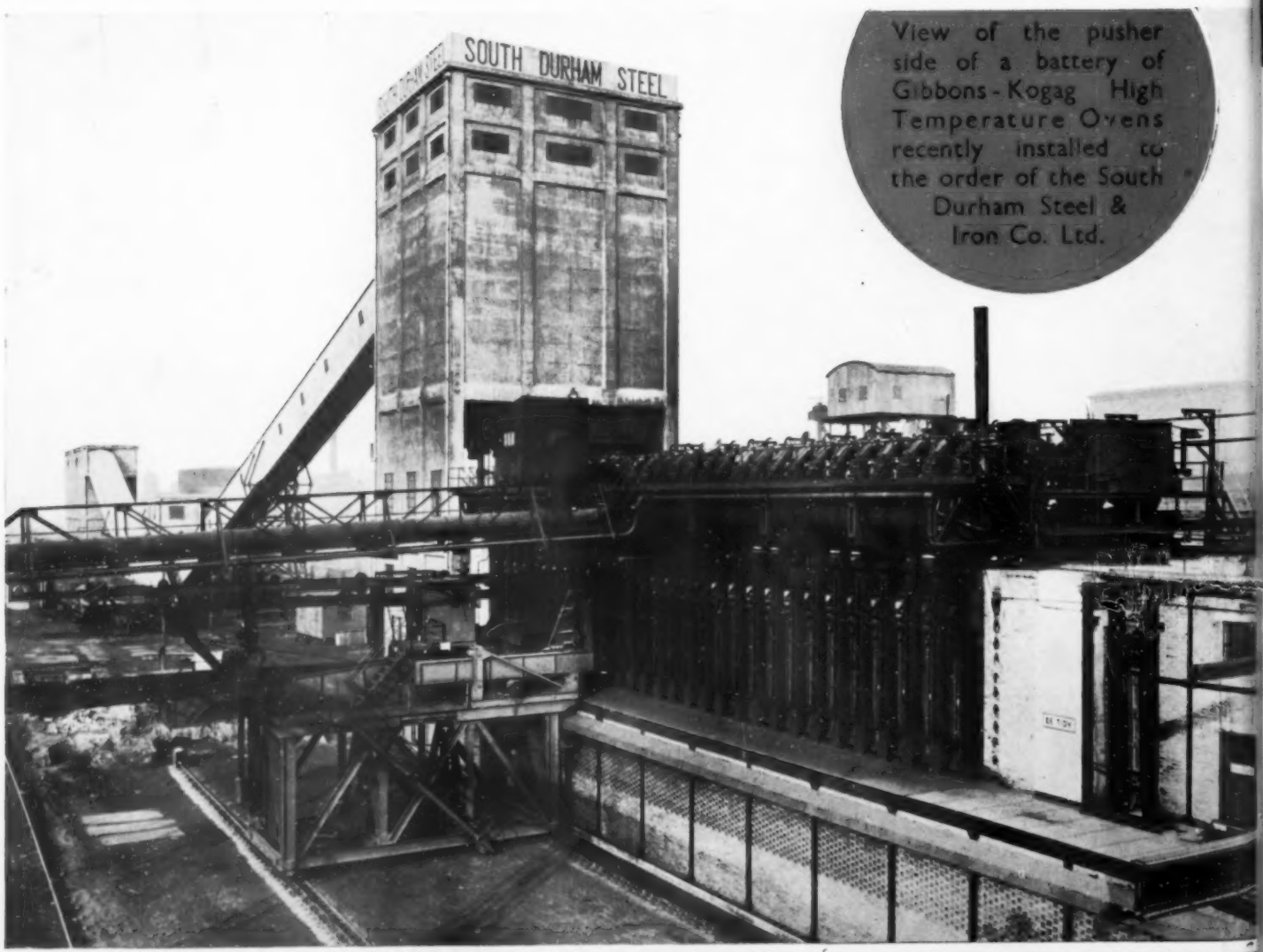

View of the pusher side of a battery of Gibbons-Kogag High Temperature Ovens recently installed to the order of the South Durham Steel & Iron Co. Ltd.

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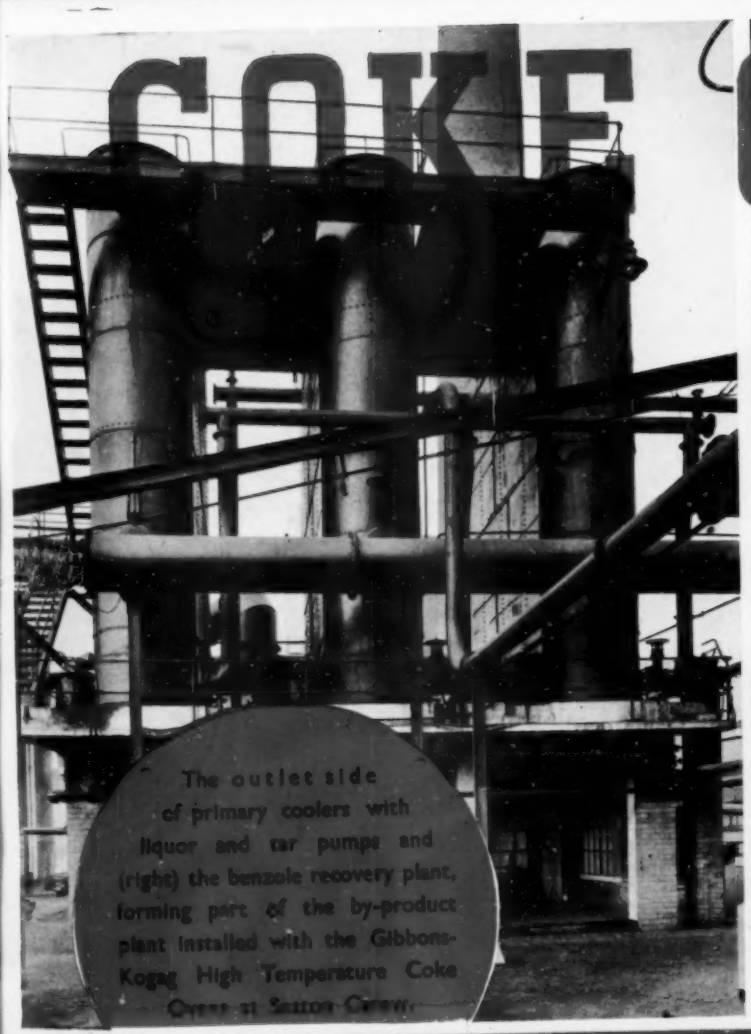
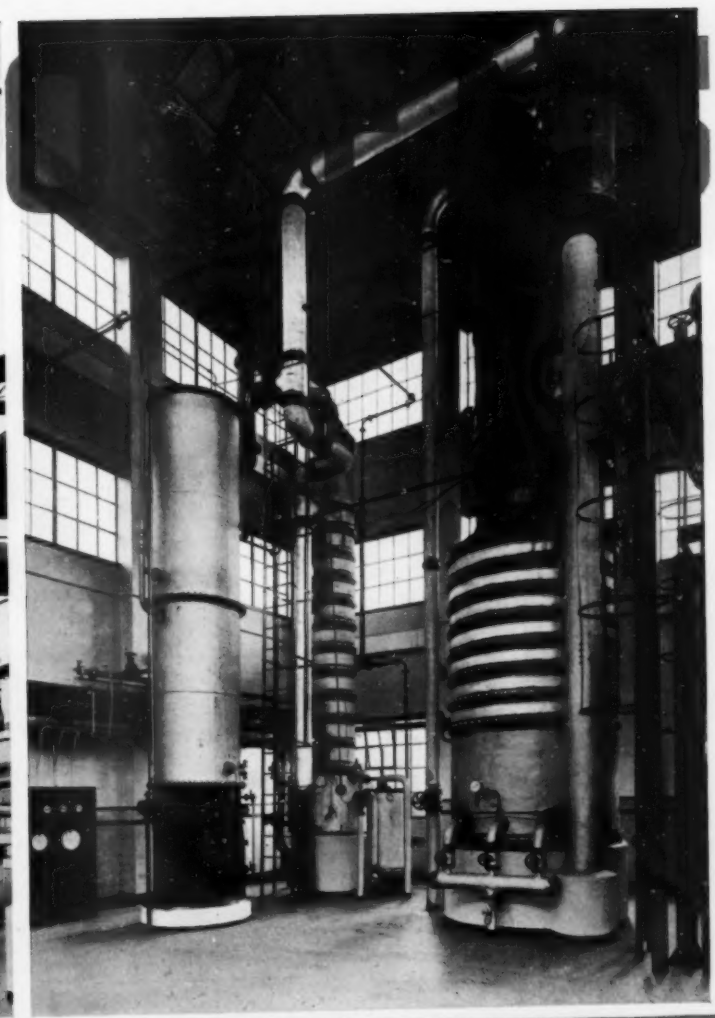


The outlet side of primary coolers with liquor and tar pumps and (right) the benzole recovery plant, forming part of the by-product plant installed with the Gibbons-Kogag High Temperature Coke Ovens at Sutton Green.



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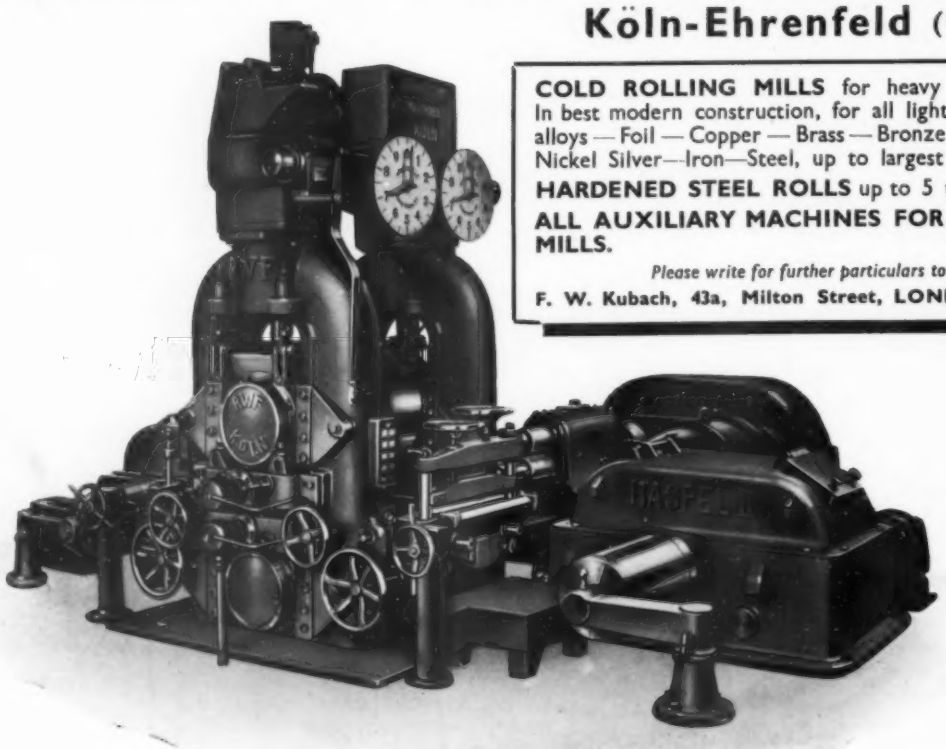

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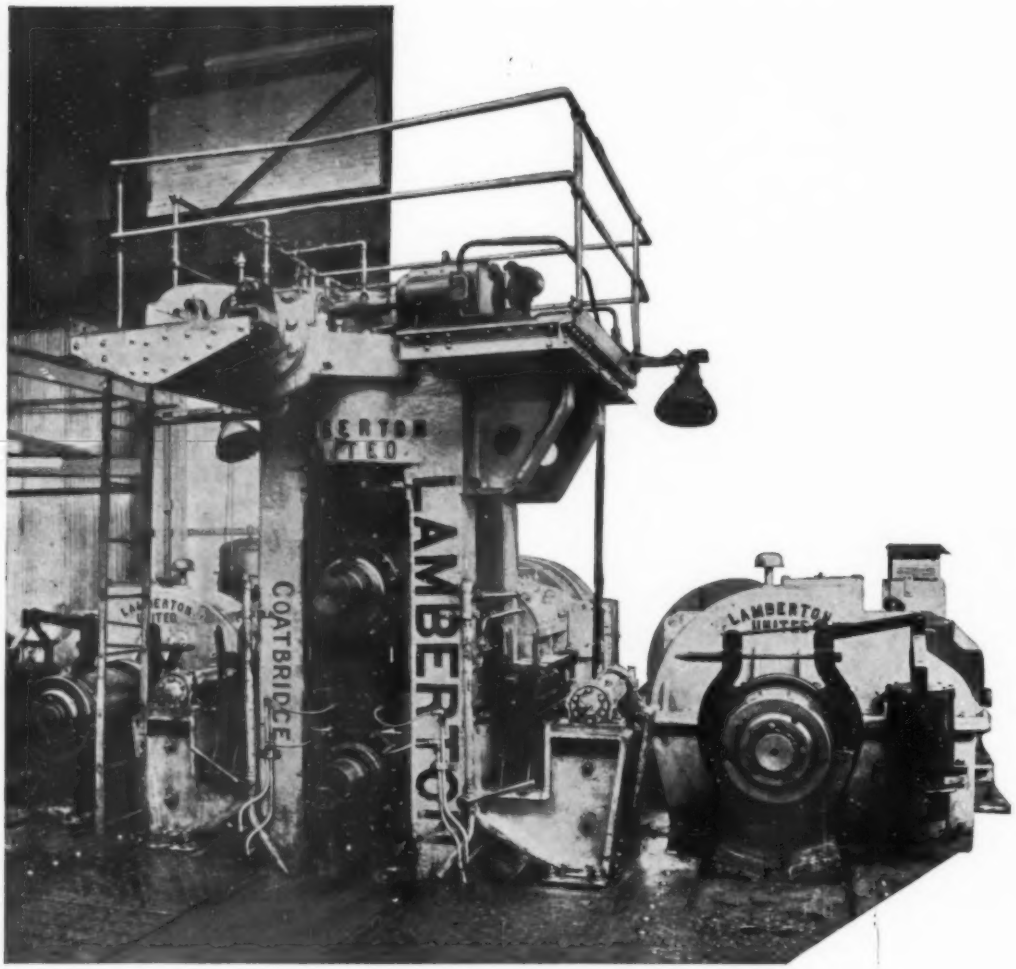

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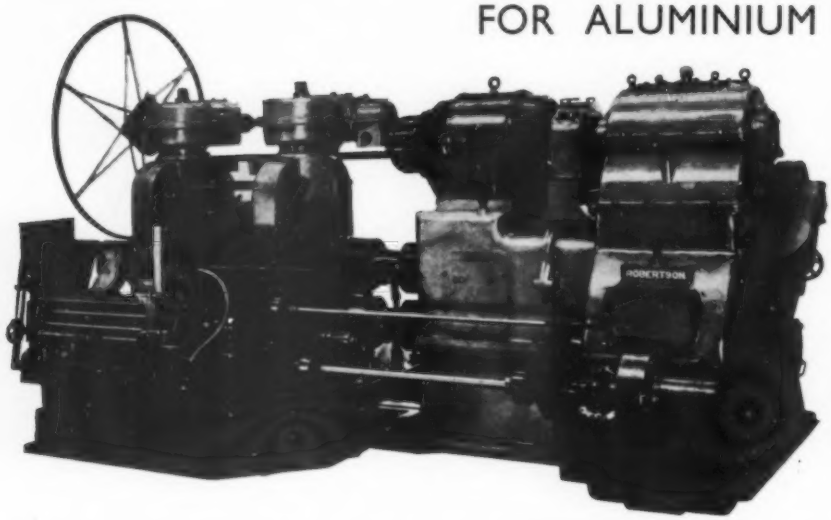

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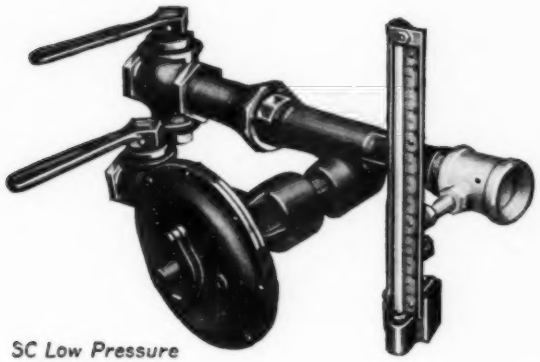

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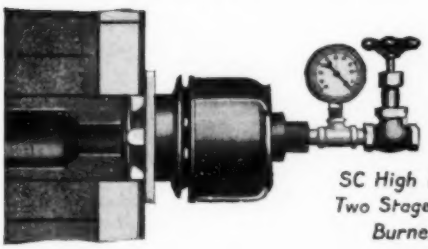

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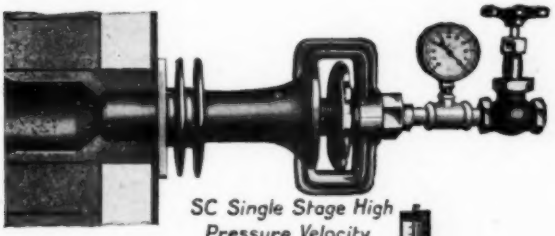

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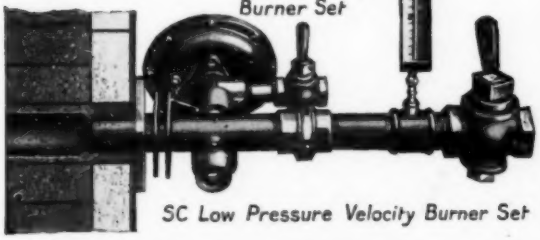

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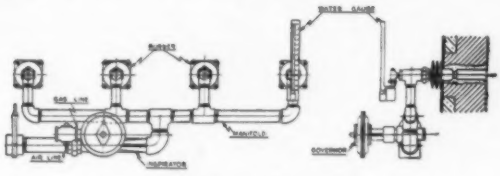
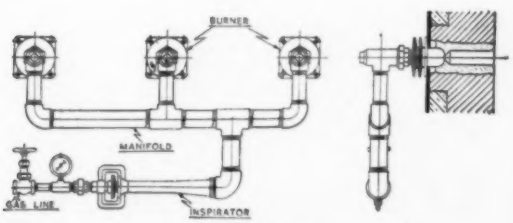


Low Pressure System



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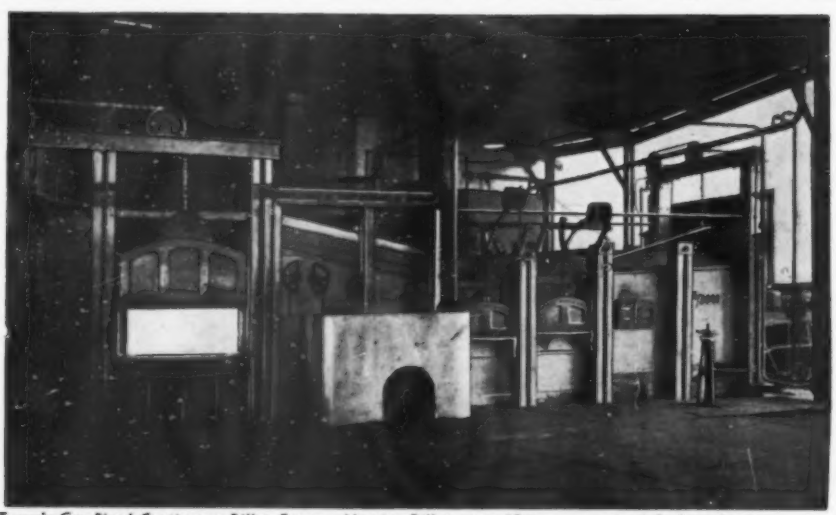

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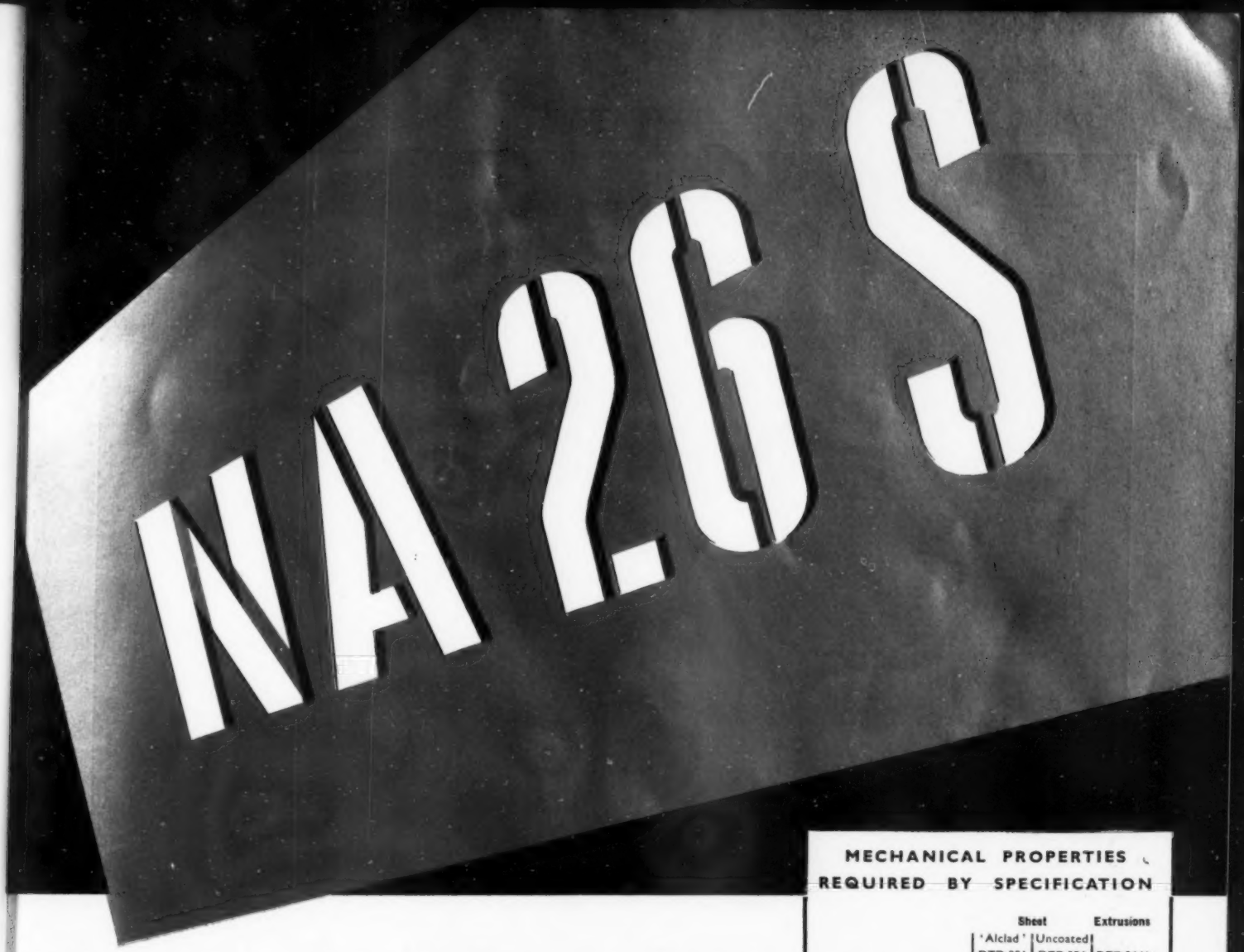

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.1% proof stress tons/sq. ins.	19.0	21.0	26
Ultimate Tensile Strength tons/sq. ins.	25.0	27.0	30
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*Proposed

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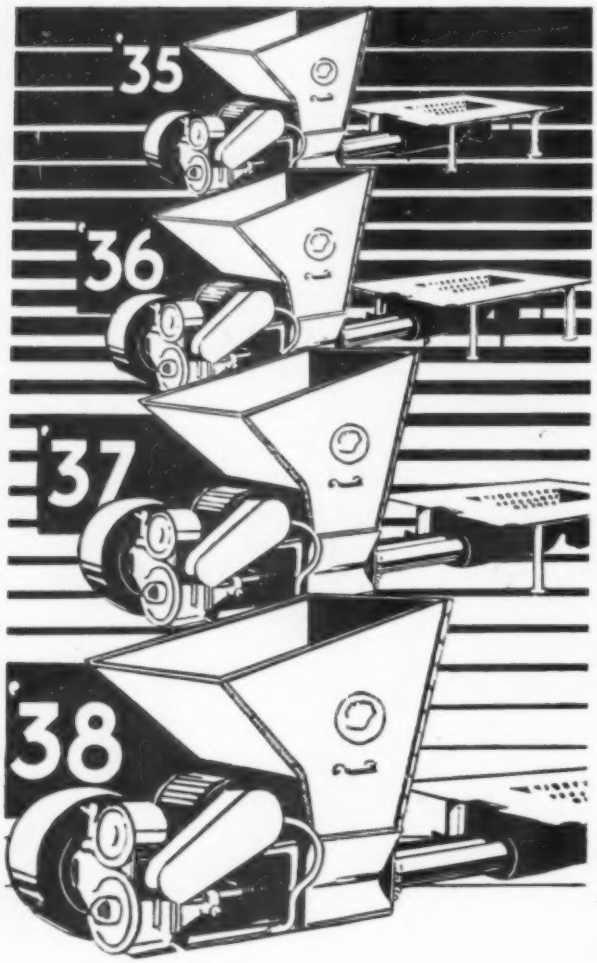

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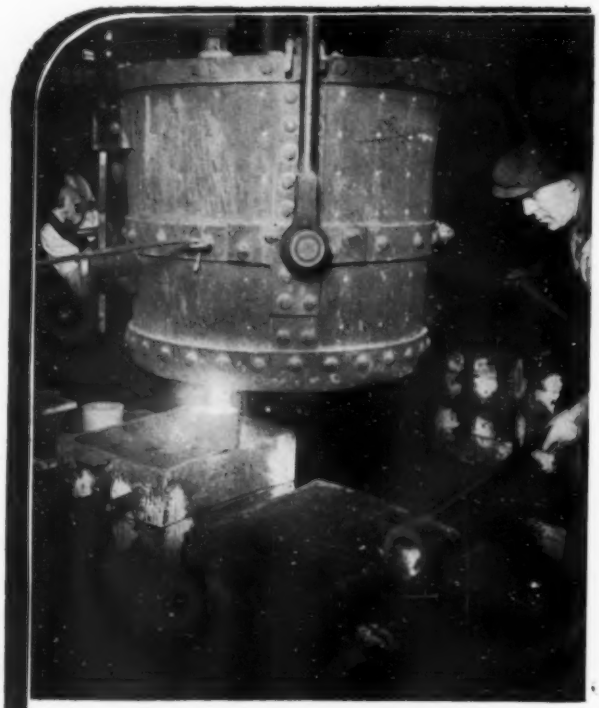

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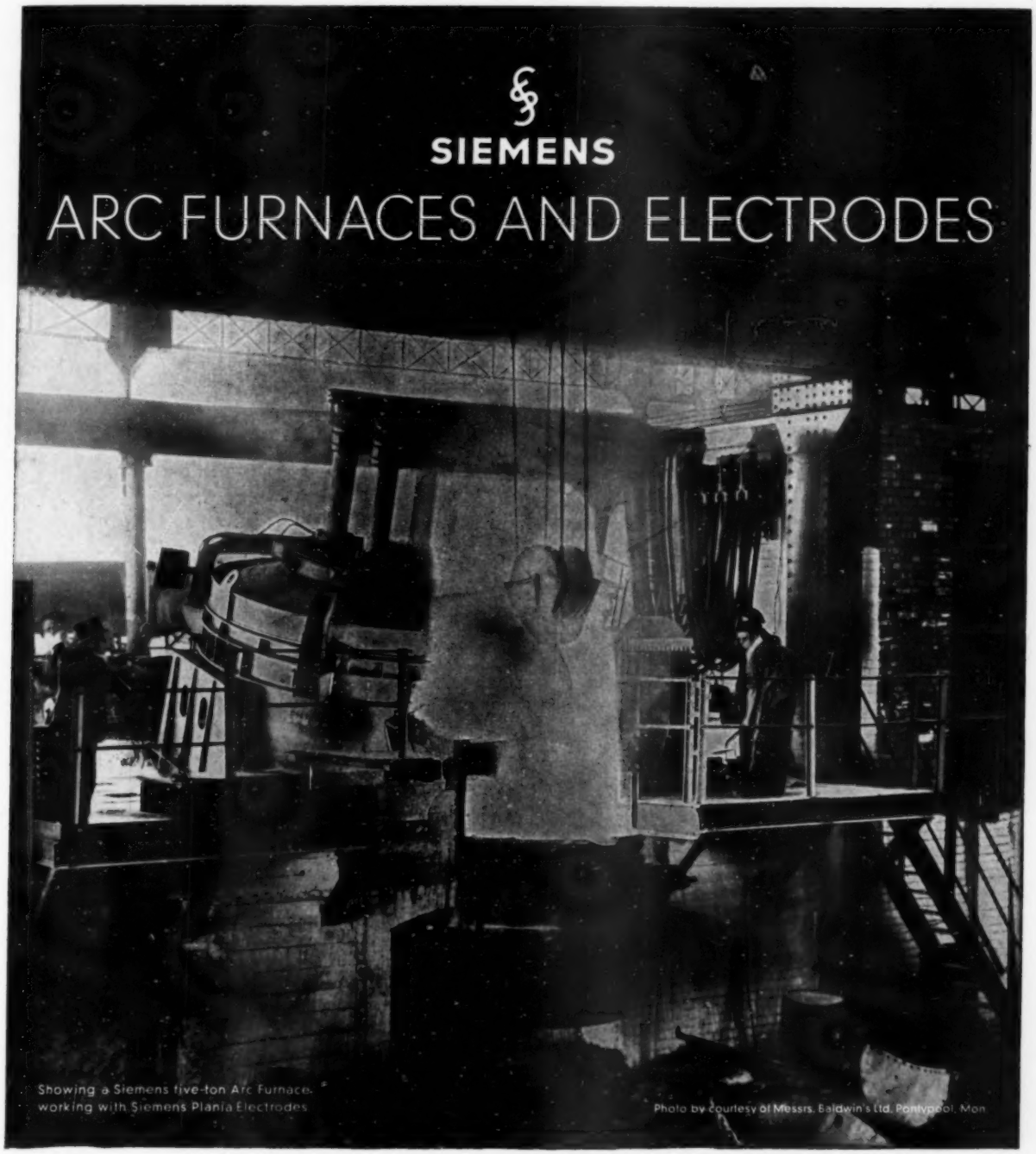
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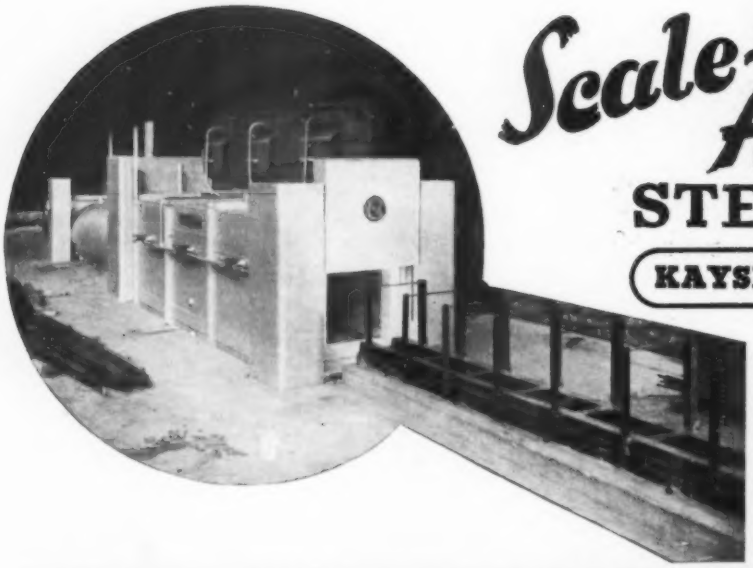

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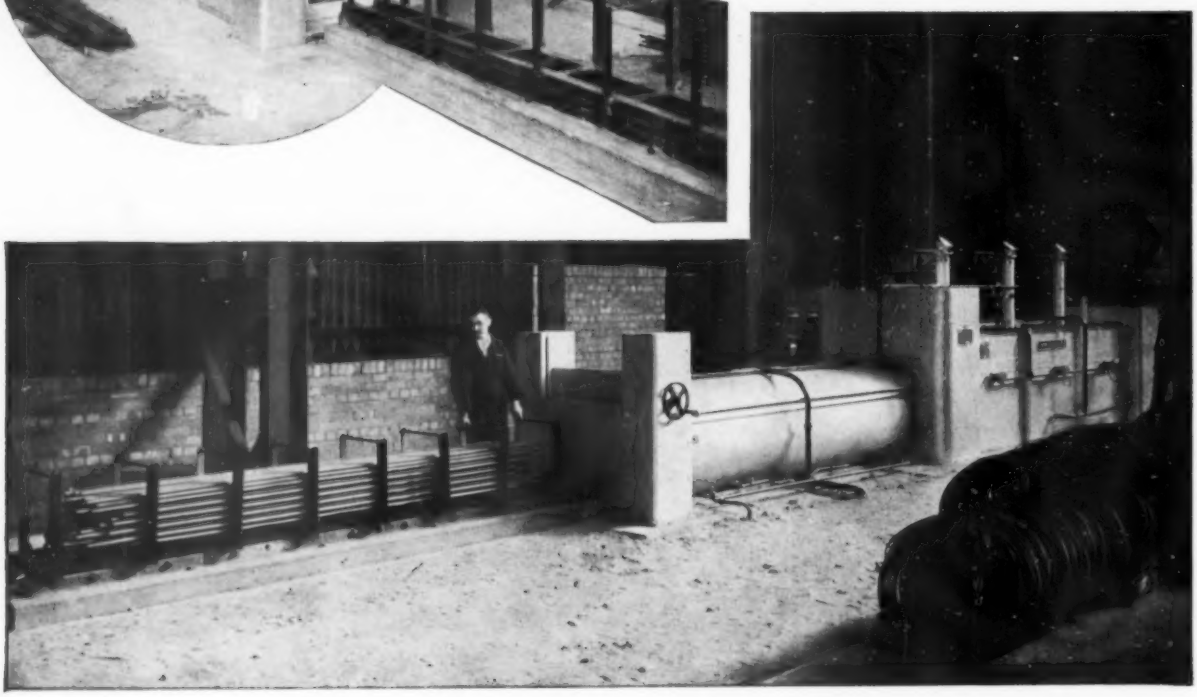

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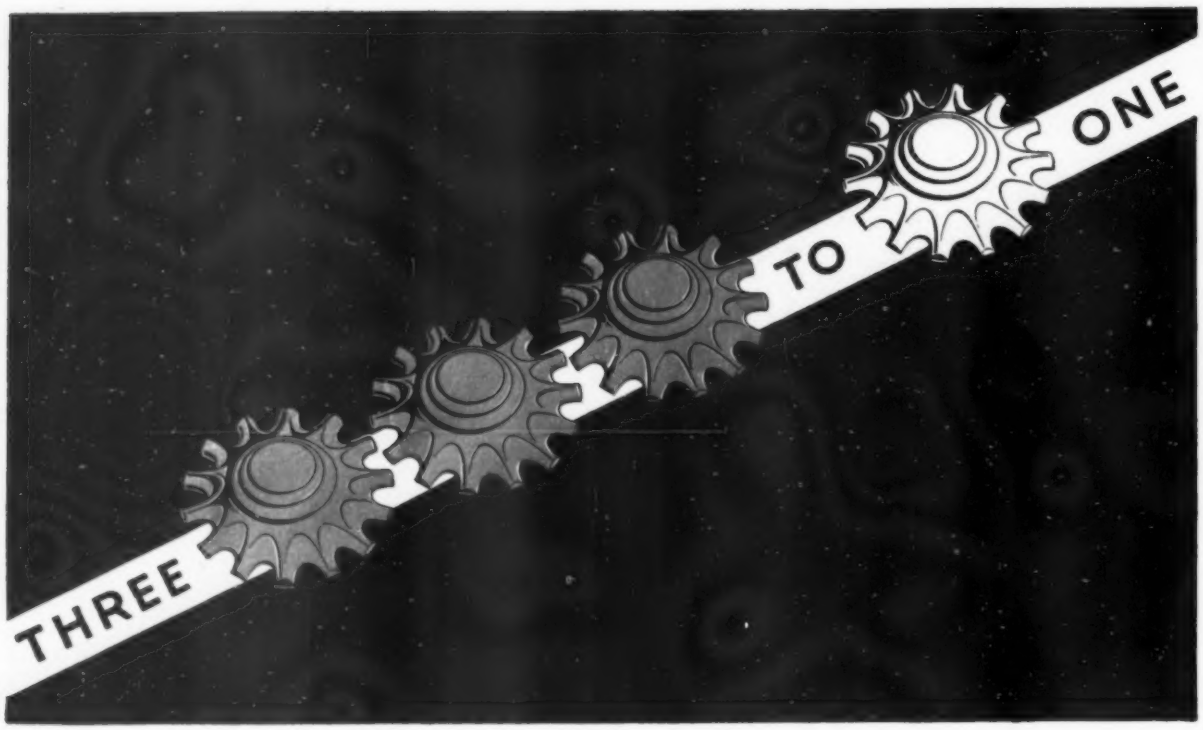

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METALLURGIA

The British Journal of Metals

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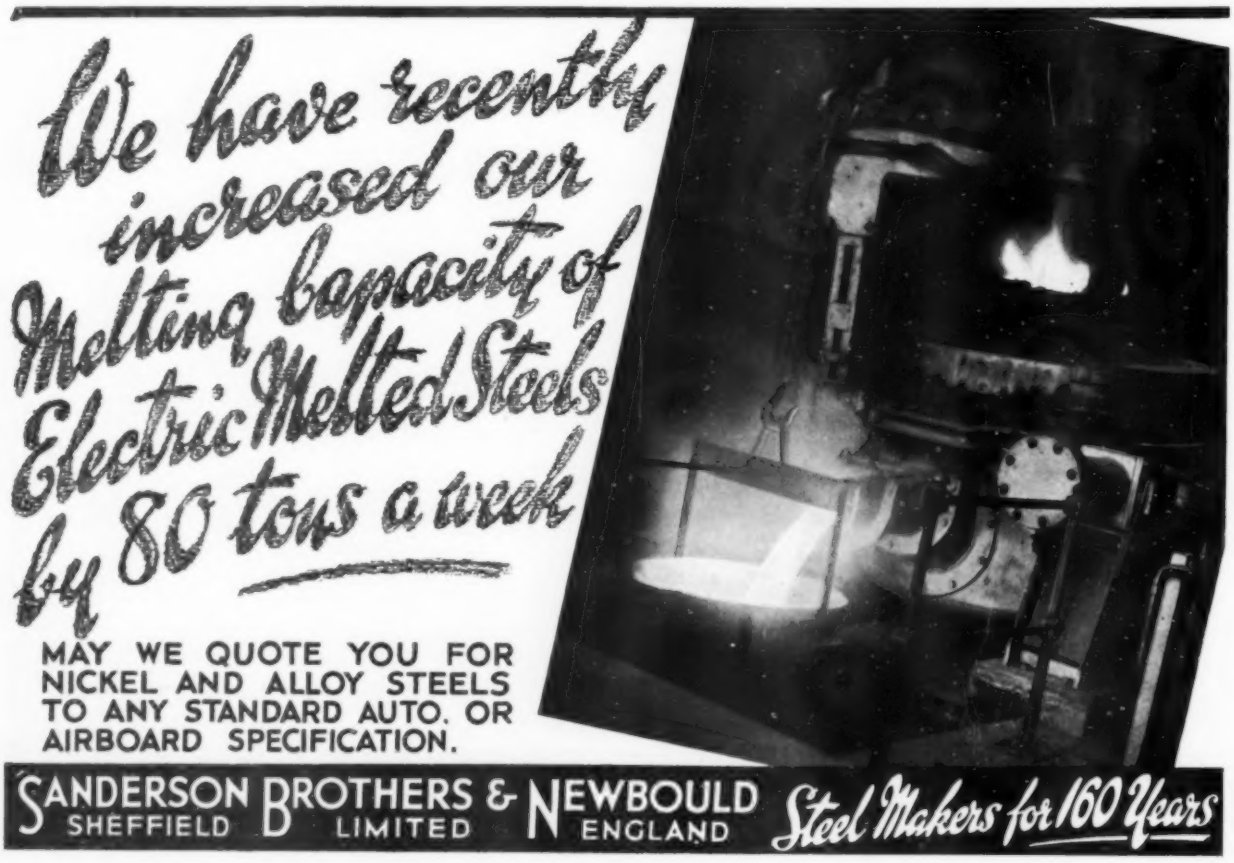
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THE BRITISH JOURNAL OF METALS.
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NOVEMBER 1938. VOL. XIX. No. 109.

New Contact Sulphuric Acid Plant

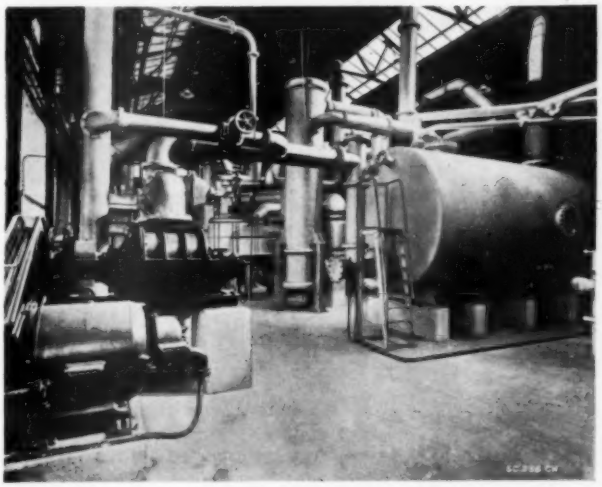
Operating on the contact system, using sulphur as the raw material, a new sulphuric acid plant has been installed at the Abbey Mills Chemical Works of F. W. Berk and Co., Ltd., which is of considerable interest; the plant is described, and some features discussed.

SULPHURIC acid and oleum are of vital national importance to the defence programme, and it is necessary to ensure adequate supplies for this purpose alone, but, in addition, sulphuric acid in particular has many important industrial uses, and without adequate supplies many industries would be severely hampered. Sulphuric acid, for instance, is used extensively in the rayon and dyeing industries, ferrous and non-ferrous industries, and for many commercial processes too numerous to mention here. It is obvious, however, that the efficient manufacture of sulphuric acid in a pure form and in sufficient quantities is of great importance, and the installation of a new sulphuric acid plant at the Abbey Mills Chemical Works of Messrs. F. W. Berk and Co., Ltd., in West Ham, is of interest to a wide range of industries.

This plant, which has been designed and erected by Simon-Carves, Ltd., of Cheadle Heath, Stockport, operates on the contact system, using sulphur as the raw material. The vanadium catalyst developed by the Monsanto Chemical Co. of America is employed, and it is this catalyst which has revolutionised the technique of acid manufacture by the contact process. It has overcome all the difficulties common to other catalysts, thereby enabling the contact process to compete successfully with the chamber method of manufacture even when strengths of acid of 80% and under are required.

Quite a number of contact sulphuric acid plants were erected in this country during the Great War, chiefly for the production of oleum, and in these a platinum catalyst was employed. With this catalyst it was essential that the sulphur dioxide gas should be thoroughly cleaned and all "poisons" removed, otherwise the conversion efficiency of the sulphur dioxide to sulphur trioxide was seriously affected. The vanadium catalyst is immune to the action of poisons, and the Monsanto Chemical Co. first put into commercial operation their vanadium catalyst some twelve years ago, licensing it to users some two years later.

During the last decade great strides have been made in the improvements of contact sulphuric acid plants by taking the fullest advantage of the immunity of the vanadium catalyst. More and more economies are being achieved not only in the capital cost of these plants, but in the cost of acid production, and these economies are largely due to simplifications in the design of the plant and the ability to build larger plants in single units. Units varying in size from 4 tons of 100% acid per day up to 100 tons per day are now in operation. Real improvements and economies have taken place in the design of contact plants. In this new plant sulphur is burnt for the production of the sulphur dioxide, and no purification system is employed, since the impurities in the sulphur do not affect the catalyst. Acid mist is eliminated by drying the air for the combustion of sulphur and for oxidation of the sulphur dioxide before entry to the sulphur burner. In addition, sulphur is admitted to the burner in the molten state, and thereby all moisture and practically the whole of the ash is removed before the introduction of the sulphur to the burner. Sublimation of the sulphur is eliminated owing to the small amount of molten sulphur present in the burner at any time.



General view of the plant showing the blowers and sulphur burner, etc., in the foreground.

The plant has a rated capacity of 24 tons daily expressed as 100% sulphuric acid, the acid being produced in the form of 94% or 98/99% or oleum, whichever is desired. In addition, there are means, previously installed, of breaking down the acid to any strength. An extremely neat, simple and compact layout is achieved, and all the vessels, towers, etc., are housed in a steel-framed brick-panelled building. The sulphur is elevated to a steel storage hopper for feeding continuously to the sulphur melter, all the sulphur requirements for the 24 hours being fed to the hopper during the day shift.

Operation of the Plant

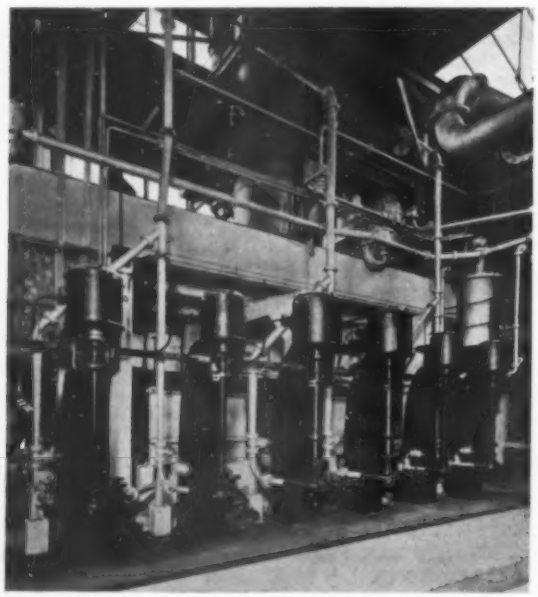
The melter is fitted with steam coils, which melt the incoming sulphur, and any dirt or foreign matter present is arrested by a system of baffles. The molten sulphur, at a temperature of 130°–140° C. is pumped to the burner, the pump employed being of the piston type, with variable stroke, to give flexibility in output, and is driven by a small electric motor through a speed-reduction gear. A spare melter and pump is installed to facilitate the removal of foreign substances that settle out. The air for combustion of the sulphur is dried by 94% sulphuric acid in a steel drying tower lined with acid-resisting bricks and filled with acid-resisting rings, a feature of this plant being the use of iron-free bricks and rings, in order to produce an acid of as pure a quality as possible.

General view of the plant showing gas coolers, filters and converters.

A spray catcher is incorporated in the top of the drying tower to arrest any acid spray from being carried along with the dried air, and which would affect the running of the blower. The air is drawn through the drying tower by a Roots-Connersville type blower driven by electric motor through a short V-rope drive. A spare blower and motor are installed complete with isolating valves, and the air is delivered under pressure to the sulphur burner.

The sulphur burner consists of a horizontal cylindrical steel tank lined with insulating brick and firebrick, the front end having a compartment of chequer work on to which the molten sulphur is delivered through steam-jacketed lines from the sulphur pump. The dried air meets the sulphur in the chequer work, and the products of combustion pass to the next part of the burner, where complete combustion of the sulphur takes place, and a gas at a temperature of about 700° C. leaves the burner containing around 7% sulphur dioxide. A steady sulphur dioxide content is ensured by the type of sulphur pump employed and the air blower. Variation in the sulphur-dioxide content can, however, be made by controlling a by-pass valve fitted between the air suction and delivery piping.

The acid receiving tanks and pumps.



The temperature of the gas has now to be reduced to around 400°–420° C. before entering the converters containing the vanadium catalyst. This is effected by passing the gases through two coolers in series, air being used as the cooling medium. The cooling air is delivered to these coolers at a slight pressure by a fan direct driven by electric motor, and the flow of air to each cooler is carefully controlled to give the gas the required temperature.

On leaving the sulphur dioxide coolers, the gas passes through a circular vessel containing a special filtering material to arrest any dust that may be carried forward. Two of these filters are erected in position side by side, but only one is in use, the other being brought into the gas stream only when the resistance in the filter becomes excessive, due to the accumulation of dust. The filtering material can then be removed, screened and replaced. Conversion of sulphur-dioxide to sulphur-trioxide is carried out in two stages, each stage being followed by a gas cooler. The oxidation of sulphur dioxide to sulphur trioxide is an exothermic reaction, and the gas after leaving the first converter is again cooled down in a steel cooler at 400°–420° C., before passing into the second converter.

80% of the conversion takes place in the first stage with the use of only 25–30% of the catalyst, the balance taking place in the second stage, where 70–75% of the total catalyst is installed. This two-stage conversion permits simple regulation of gas temperatures in order to obtain a maximum conversion efficiency; it also gives great flexibility in operating at various outputs.

After cooling with air by passage through the sulphur-trioxide coolers, the sulphur trioxide is absorbed in 98/99% sulphuric acid in two steel towers similar in construction to the drying tower, the first tower being arranged for the production of oleum. Absorption is so complete in these towers that normally no signs of sulphur trioxide can be seen issuing from the exit stack. A spray catch is installed at the top of the second absorber to ensure that no objectionable entrained acid is discharged to the atmosphere. The acid circulated over both the drying and absorber towers is cooled to the required temperature by water-spray coolers. The absorbing acid leaving the second absorber is diluted with water to maintain the strength of the acid in circulation between 98% and 99%, the optimum strength for the absorption of sulphur trioxide. The acid systems are provided with acid-resisting brick-lined circulating tanks, from which the acid jumps draw their supply. The make of acid is pumped away to storage, a connection being taken from the delivery mains to the towers. Spare pumps are installed for each circulation system, the pumps being of the vertical spindle centrifugal type direct driven by an overhead electric motor.

The control of the plant is centralised in a tiled laboratory under the drying tower, in which the instruments are mounted on one panel. These instruments comprise flow indicators for the dilution water, conductivity recorder for the absorbing acid circulation, pressure gauges indicating the pressure at various positions in the gas stream, blower pressure recorder, 6-point potentiometer type temperature recorder, giving the temperatures at the outlet of the burner and inlets and outlets of the converters, 15-point potentiometer type temperature indicator to show the temperature of the gas at other points on the plant, the air leaving the coolers and the acid temperatures.

The laboratory is fitted with a bench for carrying out acid and gas tests, the strength of 98/99% acid and oleum being checked by the "heat rise test." The Reich test is employed for obtaining the percentage of sulphur dioxide in the gas before and after conversion. Gas-sampling lines are brought to the bench for the gas tests, and in addition the blower by-pass and dilution water-feed are controlled in the laboratory.

The cooling water for the acid coolers is drawn from the base of a cooling tower by a centrifugal water pump, motor driven, and is returned to the top of the cooling tower from the concrete sump under the acid cooler by a sub-

merged vertical centrifugal pump, motor driven and provided with a float-switch for automatically stopping and restarting the pump.

Only one shift operator is required to supervise the plant and perform all routine tests, the only additional help is that required for wheeling the sulphur. Maintenance costs are very low, chiefly owing to the absence of leadwork and to the fact that only concentrated acid is in circulation. The power consumption on the plant is approximately 35 k.w.h. per ton of 100% acid produced. Conversion efficiency averages 97%, the product acid is clear, water white, and of suitable quality for use as electrolyte.

It will be appreciated that in addition to ordinary steel tankwork on this plant, advantage has been taken of metallurgical development in the use of special heat-resisting steels, acid-resisting steels, and special grades of cast iron for various important parts. The new plant, which is now in full operation, provides greatly increased production of the highest quality acids and oleum.

Moulding Materials and Practice in Non-Ferrous Foundries

The production of sound and homogeneous castings, even in the simplest shapes, is more difficult than many founders and most engineers realise, and in a recent lecture before the Midland Metallurgical Societies Mr. F. W. Rowe discussed some methods adopted and materials used in achieving the object in producing non-ferrous castings, an abstract of which is given in this article.

THE most common material for moulds for non-ferrous alloys is natural bonded siliceous sands, used either in the moist condition as prepared for moulding, or subsequently dried before casting. In recent years some substitution of natural sands has taken place by silica sands, whose natural lack of bond has been remedied by the addition of colloidal clays. The use of silica sands bonded with various resins, oils, gums and molasses has been common in foundry practice for the last 30 years. Such mixtures, when dried, have many advantage, and on account of these, some extension has taken place latterly in their use for moulds as distinct from cores. In the field occupied by moulds made from sand, easily the most striking development in recent years, is the patented cement bonded sands. This process, originally developed for iron and steel castings, has in the last two years made rapid strides in the non-ferrous metal industry, both for aluminium alloys, bronzes, and yellow metals. The basis sand is a high purity silica sand mixed with ordinary Portland cement and definite proportions of water. The resultant mixture is air setting and gives moulds of high permeability and great strength—of such strength that the ordinary box parts used to enclose normal sand moulds are not necessary.

For many reasons, the sand mould possesses many disadvantages for non-ferrous castings, and to overcome these the metal mould has been used for many years for those parts which, by reasons of shape or the quantity required, are adapted to such a method of production. In a certain limited field also development of centrifugal casting has taken place in recent years to overcome the known defects and disadvantages of the normal sand mould.

Generally, the more rapidly an alloy is cooled in the mould, the higher will be its density, hardness, and general soundness. Whilst exceptions undoubtedly exist, this is true for all but special cases. The rapidity of freezing of any one casting in a mould depends on the thermal conductivity of the mould material and the temperature at which the metal fills the mould. The casting temperature is controllable within certain limits, and it might be thought that the minimum casting temperature needed to completely fill the mould would be the best to employ. In practice, however, this does not always prove true, as imperfections in moulds and mould materials are such that less sound castings may result from the employment of a very low casting temperature, than one somewhat higher, and it is impossible, for this reason, to lay down dogmatic rules as to the best casting temperature for any particular alloy or particular class of casting.

One of the dangers and inevitable results of melting any alloy is the absorption of gases, and the amount of gas absorbed rises enormously with rise of temperature of the metal above its freezing point. Usually a lowering of the average casting temperature means a lowering of the temperature to which the metal is raised prior to pouring, which in its turn lowers the amount of gas absorbed, besides lowering oxidation or volatilisation losses. Also, the gas which is inevitably absorbed by an alloy is liable to be given off at the moment of solidification unless special inhibitors are employed or freezing is very rapid. Pinholing or similar troubles in alloys are less the more rapid the freezing, and therefore the employment of the lowest practicable casting temperature has helpful effects apart from the lower grain size and higher density. From the point of view of thermal conductivity, the sand mould is at a distinct disadvantage, and where the piece to be cast lends itself to the use of a metal mould, such is usually preferable.

A frequent practice in non-ferrous founding is to use a mould constructed in such a manner that a differential rate of freezing takes place in different parts of the casting, usually to compensate for differences in mass or sectiont of the casting, or to ensure great soundness or hardness as vital working points. This is the method known as "chilling," where metal of high thermal conductivity, usually of steel or cast iron, is incorporated in the sand mould at the points where such densening is required. Even with the use of chills, however, sand moulds do not give results equal to those obtained from metal moulds, and though their use is inevitable in a great many cases, efforts should always be in the direction of securing the highest thermal conductivity in sand moulds, by putting runners and risers in such position and of such dimensions as will enable a low casting temperature to be used and by using chills on the thicker portions of the castings, or at points where great soundness is essential.

Centrifugal casting has been practised for nearly a hundred years, but the use of the vertical axis mould and the methods used for gearwheel blanks and similar parts is a more recent development. In centrifugal casting, the action is such that metal is being continually fed by centrifugal force into the freezing castings, and providing conditions are right, automatically compensating for the liquid shrinkage. Another advantage of centrifugal casting is that the constant vibration and agitation of centrifugal casting during the whole period of solidification prevents the growth of large crystals, with the result that the casting is finer in grain than a stationary casting made under similar conditions with regard to mass and casting temperature. Another advantage of centrifugal casting is that the

difference in physical properties between a small casting and one of large mass is not so large as in sand or even in chill castings. Whilst most of these statements refer to castings produced in moulds with a vertical axis, similar results are obtained on the horizontal axis mould.

Small light castings, where the quantity is not sufficient to justify a metal mould or the alloy or shape of the casting is not one which lends itself readily to such production, will continue to be made by the green sand method of moulding. Where important castings of anything above the lightest weights are concerned, most bronze foundries prefer a dry sand mould on account of the greater strength and reliability of such moulds. With the increasing use of sand control, however, both as regards grain size, permeability, moisture content, etc., and in particular with the advent of sands bonded with colloidal clays, there is no doubt the field for green sand work could be increased. The green sand mould possesses undoubted advantages of giving sharper casting with a smoother skin and less flash, and thus less fettling costs, and its extension to more important work by the use of synthetic sands promises a very favourable field. The advantages of a properly made synthetic sand are that the permeability is greater and more regular than a normal green sand, and that a much greater strength can be obtained.

Materials Used in American Aircraft Production

FROM the standpoint of manufacturing in large quantities, metals offer greater possibilities than wood for aircraft, said Mr. T. P. Wright, in a recent lecture before the Royal Aeronautical Society on "American Methods of Aircraft Production." Referring briefly to the metals used, he stated that alloy steels, particularly chrome molybdenum, play an important part in American aircraft construction. It is used in tubing and forged form for engine mounts, landing gears, and highly stressed fittings. Nickel steel, for the most part, is used for bolts and similar parts. In general, non-ferrous metals other than alloys of aluminium, play a relatively unimportant part, although quite a few copper and nickel alloys are found in many American planes. Brass and bronze are used to a limited extent. Some bronze castings are used, and brass in the form of machined bar stock for hydraulic fittings and the like occurs quite frequently.

Aluminium alloys, however, are by far the most important in American aircraft construction. Aluminium has a good ratio of strength/weight, is workable, and sufficiently inexpensive to make it attractive. It is particularly well suited to use in the stressed skin type of construction so prevalent in America at present. It is used extensively both in the forms known as Duralumin and Alclad; in the latter in aircraft for American Air Corps and for our civil users; while in the former, anodically treated, it is preferred, rather illogically, for naval aircraft. With increasing structural design efficiency, the problem of securing adequate rigidity is becoming of great importance. Duralumin is only fair in this regard. Although this material is eminently suitable for stressed skin construction, yet from the standpoint of reduced complication we could perhaps wish for one of even lower specific weight in order that for given weight/strength requirements, greater skin thickness could maintain, thus further reducing the need for stringers and stiffeners.

Some feel that magnesium has possibilities in alloy form to supplement or supersede aluminium alloy. However, certain characteristics of magnesium alloys have not proved particularly desirable, and so far the chief uses of magnesium are in the form of castings, where the material is used extensively for landing chassis wheels, levers, tail-wheel forks, and rudder pedals, with some additional use in sheet form for housings, etc. It seems quite likely to Mr. Wright that eventually alloys of magnesium will be developed which can properly be used more extensively for structural purposes.

Forthcoming Meetings

IRON AND STEEL INSTITUTE.

Dec. 2 and 3. Additional Autumn Meeting at Cardiff. Programme includes a Technical Session in South Wales Institute of Engineers, on December 2, at 7-30 p.m. Visit to the East Moor Works of Messrs. Guest Keen Baldwins Iron and Steel Co., Ltd., on December 3, at 9-30 a.m.

INSTITUTE OF METALS.

BIRMINGHAM SECTION.

Dec. 1. "Light Alloys for Aircraft," by H. Sutton, D.Sc.

LONDON SECTION.

Nov. 25. Supper-Dance. (Thames House, Millbank), 7-30 p.m.

Dec. 7. "Modern Non-Ferrous Foundry Practice," by F. Hudson, at Charing Cross Hotel, at 8 p.m. (*Joint meeting with London Branch of the Institute of British Foundrymen.*)

NORTH-EAST COAST SECTION.

Dec. 13. "Aluminium Alloys in the Foundry," by R. Givern, B.Sc.

SWANSEA SECTION.

Dec. 13. "The Relationship between the Mechanical Properties of Metals and the Liability to Breakdown in Service," by L. W. Schuster, M.A.

MANCHESTER METALLURGICAL SOCIETY.

Dec. 7. "Powder Metallurgy," by W. D. Jones, M.Eng., Ph.D.

STAFFORDSHIRE IRON AND STEEL INSTITUTE.

Dec. 6. "Roll Camber in Strip Mills," by S. C. Larke.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

Nov. 18. "The Utilisation of Steam for Power and Heating in Industry," by G. L. E. Metz, C. L. G. Hyde, B.Sc., and J. H. Belcher.

Dec. 2. "Forced Circulation Boilers and Their Applications for Marine Purposes," by Capt. R. E. Trevithick.

INSTITUTE OF BRITISH FOUNDRYMEN.

BIRMINGHAM BRANCH.

Dec. 2. "Foundry Melting Furnaces," by S. E. Dawson, F.I.C.

EAST MIDLANDS BRANCH.

Nov. 19. "Mechanisation in the Foundry," by P. C. Bleakman (at Derby).

LINCOLNSHIRE SECTION.

Dec. 12. "Time and Motion Studies in the Foundry," by C. D. Pollard.

LANCASHIRE BRANCH.

Dec. 7. "Graphite Structure and Porosity," by W. West and C. C. Hodgson.

LONDON BRANCH.

Nov. 25–26. Joint Meeting with the Sheffield Branch.

Dec. 7. Joint Meeting with Institute of Metals. "Modern Non-Ferrous Foundry Practice," by F. Hudson.

MIDDLESBROUGH BRANCH.

Dec. 3. Joint Meeting with Newcastle Branch. Visits to (1) L.N.E.R. North Road Locomotive Works, and (2) Thos. Summerson and Sons, Ltd., Darlington.

NEWCASTLE-ON-TYNE BRANCH.

Nov. 26. "A Chemist Looks at the Foundry," by J. Stott.

Dec. 3. Joint Meeting with Middlesbrough Branch.

SCOTTISH BRANCH.

Dec. 10. I. "The Production of Certain Iron Castings," by J. Roxburgh.

II. Annual Dinner at Grosvenor Restaurant.

FALKIRK SECTION.

Nov. 19. "A Talk on Sands," by T. Tyrie, B.Sc.

SHEFFIELD BRANCH.

Nov. 25–26. Joint Meeting with London Branch.

Dec. 1. "Report of Cast Iron Sub-Committee on the Properties of Cast Iron." (Presented by P. A. Russell, B.Sc.

WALES AND MONMOUTH BRANCH.

Dec. 10. Joint Meeting with Newport Metallurgical Association. "Ingot Moulds and Steel Rolls," by Dr. A. R. Everest, B.Sc. (at Newport).

BRISTOL SECTION.

Dec. 3. "Hydraulic Pumps and Rams," by F. G. Jackson.

WEST RIDING OF YORKSHIRE.

Dec. 10. "Report of Cast Iron Sub-Committee on the Properties of Cast Iron." (Presented by G. L. Harbach.)

METALLURGIA
THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER"

Trade and Industrial Outlook

SINCE the early months of this year trade and industrial production have shown reductions, and until recently reports from various industrial centres in Great Britain did not indicate any likelihood of an early reversal in trade. The speeding up of the rearmament programme, at least up to the time of the recent crisis, had been insufficient to offset the contraction either in export orders or in the home demand, and had no appreciable affect on the number of unemployed. It was somewhat surprising, therefore, that Mr. Chamberlain, speaking in the House of Commons, should give an official welcome to the coming industrial revival, and express the hope that another upward turn would succeed the present recession, since the main cause—the fall in commodity prices—had been arrested.

The hope expressed, of course, only echoed the wish of many, but to officially welcome an industrial revival seemed to convey a degree of optimism not supported by facts. Recently, however, signs of recovery have been perceptible, and reports now indicate that these give promise of developing favourably. How far this recovery is due to the placing of orders deferred during the period of the crisis or to a definite improvement in trade, it is difficult to say, but trade has improved in cotton, wool, and other textile trades; in coal mining; in iron and steel manufacture; in non-ferrous metal manufactures; in aircraft and motor-vehicle manufacture, to mention only a few of the main industries.

The most definite signs of improvement are shown by the iron and steel industries, for which the October figures indicate a substantial increase on the previous month. The output of steel ingots and castings amounted to 854,800 tons, an increase of 11·3% on the September output, the rise on the month being the best recorded in the last ten years. At 469,400 tons the pig-iron production increased by 9·2% on the September figure. These returns reflect the acceleration of the armament programme, but there has also been increased demand in the home market for normal commercial purposes and good demand from the foundry trade has been experienced in the pig-iron section. The steady reduction in stocks is an encouraging feature, and inquiries from overseas buyers are also encouraging, especially if the Government's determination to create conditions under which industry can carry on its work with confidence and success results in the restoration of confidence.

Much of the difficulty under which the iron and steel industry has laboured this year was due to the frenzied buying of pig iron and scrap in 1937, when the home output could not meet the demands and import restrictions were eased to facilitate imports; in this manner stocks rose to such an extent that only now, with the depletion of stocks, are there indications of recovery. In this connection the suggestion of Sir Walter Benton Jones, of United Steel Companies, Ltd., is noteworthy. He suggests that the steel trade should organise the storing of pig iron in lean times and draw on its reserves when the demand is high. In addition, he considers that the collection of scrap should be organised on improved lines, with the object of speeding up the long journey of scrap material to the steelworks. Action on these suggestions would ensure to the steel trade an adequate supply of raw materials, and would create a steadier balance between periods of low and high demand.

That the industrial outlook is considered favourable is also indicated by the drastic decision of the restricting copper producers entirely to suspend restriction of output. By suspending output control at a time when the current production quota is still 95% of standard tonnages, instead of stepping up production by degrees, those responsible for restriction have shown they have no wish to repeat the mistakes of 1937. The increase of 10% in quotas, previously announced, was interpreted as confirmation that the trend of consumption was favourably regarded, but recently the market has shown a tendency to develop boom conditions, and to prevent prices soaring, the decision to suspend restriction of output has been made.

Although there are definite indications of improvement, we are far removed from what is termed boom conditions. The basic industries are still far from working to capacity, and overseas markets should be explored more thoroughly, so that output can be increased and unemployment reduced. Exports are of vital importance to this country, and Mr. Chamberlain has always laid stress upon this objective. Recently, when speaking on his policy of European appeasement, he expressed a determination not to allow British trade to be thrust out of South-Eastern Europe. But the price factor is generally the most important consideration in maintaining exports to overseas markets, and only by keeping plants and factories operating at or near their capacity can the price of our exports be regarded as competitive. It is foolish to say that an extension of the export trade might some day be required to take up a slackening of internal demand. An extension of the export trade is more necessary to-day than at any time in the history of Great Britain; this is the greatest importing country, and to continue to import raw materials the export of manufactured goods is essential. There has never been a day when the extension of the export trade was other than desirable, and surely never will be until all the unemployed are absorbed by industry.

The British Government cannot afford to neglect any reasonable and practicable means of increasing the country's exports. For some time this country has experienced a very large excess of imports over exports; the demands of the armament programme has increased the need for imports and reduced the supplies of goods available for export, but, important as rearmament undoubtedly is, it should not be used to hinder the development of the export trade. At the moment, there seems to be considerable uncertainty regarding the future of British trade policy in face of the State organised and assisted competition of certain European competitors in our export markets. The employment of subsidies and internal levies for exports, the conclusion of agreements of pacts with other countries, and the use of our great purchasing power to induce other countries to expend a fixed percentage of their sterling receipts on British goods, deserve very careful examination in an effort to improve British export trade. It is probable that the Anglo-American trade negotiations which have been in progress for some considerable time, will shortly be concluded and an agreement signed. This will help, but a sound policy is necessary to maintain British leadership in the industrial competition of the nations and it is the Government from which industry seeks such a policy.

Powder Metallurgy

THE difficulties associated with platinum melting some one hundred years ago led to the use of precipitated platinum powder which was pressed into small billets and then sintered at a temperature below the actual melting point of the metal. The process was also applied to iridium. That was the beginning of powder metallurgy. It is pointed out by G. J. Comstock* that early experimenters found that pressing precipitated platinum powder into the small billets mentioned, sintering the mass to a degree that would permit satisfactory hot forging, while repeated heat-treatment and forging gave a strong and dense, but ductile, metal from which articles could be manufactured without the difficulties attendant upon casting.

There is one very interesting and significant comparison between metal-powder products and alloys of similar composition. Whilst alloys produced by normal melting and casting generally possess properties of their own, as distinct from those of the metals from which they are made, certain of the products of powder metallurgy, when made without diffusion alloying, exhibit the original characteristics of their constituent metals very nearly in direct proportion to their presence in the resulting metal. This immensely widens the scope of their application, especially in such specialised work as for electric circuit breakers and for other applications where the properties required are apparently of an opposing nature. The use of copper with tungsten, or silver with nickel, molybdenum, graphite or tungsten, are cases that illustrate this point.

In reviewing the earlier use of powder metallurgy, Mr. Comstock brings out two important factors : that of heat-treatment and forging following the original pressing of the powder. The development of the practice is seen in the fact that hard cemented carbides are made by cementing the hard metallic carbide particles by mixing them in powder form with a minor proportion of a lower melting-point metal powder, this being pressed and heated to a temperature which is sufficient to promote liquefaction of the lower melting metal. When cool, this liquid metal solidifies, thus cementing the carbide particles one to another. Here, too, the resulting product shows the characteristics of the carbide and of the matrix in almost direct proportion to their presence in the composition.

Perhaps even more significant in its effect on metal-powder technique was the production of tungsten lamp filaments. The casting and contamination difficulties which were incident to the manipulation of that extremely refractory metallic element undoubtedly suggested the employment of means which were similar to those which had earlier proved so eminently satisfactory for platinum under similar circumstances. Metallic tungsten in powder form was also available by precipitation and reduction. It, too, was found to be capable of consolidation by the application of heat to billets which were pressed from the powder. The true melting temperature of the metal, 3,400° C., was not required for promoting particle to particle welding in such billets. Hot-forging the forms which had been heat-treated in this manner improved their strength and ductility to an extent which ultimately permitted their cold deformation by modified wire-drawing practices. By these means the finest of wires were ultimately produced from the most refractory of metals.

Molybdenum and tantalum are reproduced by very similar means, this making them available in the form of sheet, strip, rod, wire and fabricated articles. The main commercial products manufactured in any quantity from metallic powders are the three named refractory metals ; materials for electric contacts and electrodes ; porous bearings ; and hard cemented carbides for tool-work.

Porous bearings consist essentially of copper, tin and graphite. These are combined as powders with a lubricant and pressed to the desired form. It will be realised that this permits the formation of unusual structural effects, such as would not be possible to achieve with casting. After forming, the bearings are heat-treated to promote diffusion and alloying between the copper and the tin particles, this giving a regulated porosity. They are then sized to finished limits in dies and impregnated with oil, this being sufficient for several million revolutions as a rule.

Powder metallurgy enables the operator to avoid difficulties associated with casting and/or melting, allows special structural effects to be secured, and there is the valuable feature that fine metal aggregates which exhibit the individual characteristics of their metallic constituents can be produced by this means and that such combinations do not call for the selection of metals which possess affinity for one another. The application in the electrical industry and for tool tips should be but two of a widening application for this comparatively new technique.

* G. J. Comstock. *Mech. Eng.* 1938, 60, 11, pp. 801-6.

Aircraft Production

FEATURES of the first issue of the new monthly publication under the above title will include a description of the Austin shadow factory, in which are produced Fairey battle bombers, an article stressing the importance of co-operation between production and inspection by Lt.-Col. H. W. S. Outram, C.B.E., the new Director of Production (Aircraft), a description of the manufacture of aircraft radiators, an article describing the spot-welding methods of a pioneer German firm, descriptions of special French and American plant, as well as regular features which include a review of selected British and foreign machine tools, small tools, and shop equipment.

This is a high-class technical journal published by Iliffe and Sons, Ltd. It will appear on the fourth Wednesday in each month, commencing this month ; price 1s., annual postal subscription rate 16s., Canada 13s. 6d.

Iron and Steel Institute

ARRANGEMENTS have been made to hold an additional autumn meeting in Cardiff on December 2–3. The programme arranged includes a Technical Session, to be held in the Lecture Theatre of the South Wales Institute of Engineers, Park Place, Cardiff, on December 2, at 7-30 p.m. Two papers contributed for the autumn meeting by authors in the United States of America will be presented for discussion. At this meeting the chair will be occupied by Mr. J. S. Hollings, joint managing director of Messrs. Guest Keen Baldwins Iron and Steel Co., Ltd., and the following papers will be presented :—" The Development of the Open-hearth Steelmaking Processes in Recent Years in the United States of America," by L. F. Reinartz ; " American Soaking Pit and Reheating Furnace Design and Practice," by F. M. Gillies and E. D. Martin.

Arrangements have also been made for members to visit the East Moor Works, Cardiff, of Messrs. Guest Keen Baldwins Iron and Steel Co., Ltd., on December 3, at 9-30 a.m. It is proposed to visit the following departments : Coke Oven and By-product Department ; Blast Furnace Plant ; Basic Open-hearth Melting Shop ; Cogging Mill ; Eight Stand Continuous Billet Mill ; Three-high, Three-stand Light Section Mill, etc.

Sir Walter Kent

We regret to learn of the death of Sir Walter Kent, managing director of the firm of George Kent, Ltd., which recently celebrated its centenary. He passed away on November 11. It is noteworthy that the firm of George Kent, Ltd., had been controlled for over 100 years by Sir Walter and his father, the founder of the firm. Sir Walter was well known and very highly respected, especially in the Luton area, and his loss will be keenly felt by a very wide circle of friends.

Further Experiments in the Working of Malleable Cast Iron

By John V. Murray

Experiments on the hot- and cold-working of malleable cast iron are described and a consideration of the results indicate that whiteheart malleable iron can be cold- or hot-worked providing adequate metallurgical control is maintained in the process of manufacture and subsequent operations. Applications are suggested.

IN experiments previously described[1] the work was finally conducted at a temperature well below the A arrests, and it was decided to conduct a full series of cold-worked bars to try out the effects of cold-rolled work from the commencement to the finish. It was expected that the material would roll out, but efforts were made to find out the most suitable temperature for any intermediate anneals. As whiteheart malleable increases in combined carbon from nothing on or near the surface to about 0·8% in the centre, the annealing temperature which suits the surface area would not do for the centre, but a temperature suitable to both was a possibility.

Experiments were also conducted in other types of hot- and cold-work, which are described here. Many of these will find useful application, because in almost every case the extra work resulted in enhancing the physical properties of the material. In some cases the whole of the machining can be abolished or reduced to a minimum, but, as will be shown, the operations, from the casting to the finished product, must be metallurgically controlled, otherwise failure and disappointment will result.

Experiments in Cold Rolling

The original bars were 6 in. × 2 in. × ½ in. in size. They were annealed for six full days at a temperature of 980°–1,000° C. independent of heating and cooling. After cleaning thoroughly by sand-blasting they were cold worked as follows :—

1. Nine passes of $\frac{1}{32}$ in. and four of $\frac{1}{64}$ in. caused many cracks to appear on the surface and on the edges. This of course was more or less expected, and as these bars were spoiled it was decided to give intermediate anneals. The hardness was 187 Brinell, which is not very high in view of the length and breadth of the cracks.

2. The bars were cold-rolled with eight passes of $\frac{1}{32}$ in., and at each pass they became hotter and harder. There were no cracks apparent to the eye, and none were found microscopically. Their appearance was exactly as steel, and just as polished. 130 Brinell indicated a ferritic surface. It was decided to anneal these bars and further cold roll them. The temperatures decided upon were 680° C. and 900°–925° C.

3. Annealed at 680° C. for 30 mins. The bars which had already been reduced as in Experiment 2 were given four passes of $\frac{1}{32}$ in., six of $\frac{1}{64}$ in., and one of $\frac{1}{128}$ in. This latter caused the bar to split almost in two longitudinally down the centre of the bar as shown in Fig. 1 ; the Brinell number was 340.

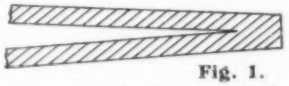


Fig. 1.

4. Annealed at 900°–925° C. The bars were given four passes of $\frac{1}{32}$ in. reduction, six of $\frac{1}{64}$ in. and four of $\frac{1}{128}$ in. No trace of splitting was apparent, and the bars, greatly elongated, left the rolls in an excellent condition. This was the absolute limit of the rolls, and the product only like tinplate. The Brinell number of these was 402.

This bar was examined microscopically. The absolute end was composed entirely of ferrite, but as the centre was approached the pearlite and ferrite were intermixed, forming a series of waves, as shown in sketch.

Even the nodular carbon took this shape. The oxidised edge rolled out equally as well as the interior. The centre of the bar is almost wholly pearlitic. High magnifications were necessary to resolve it. Ferrite is crushed down intimately with the pearlitic, although some persists even in the centre.

Smaller Sized Bars

5. Bars 8 in. × 1 in. × ¼ in. were rolled down to $\frac{1}{64}$ in. in nine passes. These splay out as in Fig. 2, but in this case the centre bars did not split all the way. The shape of the bars is shown. The Brinell number was 277, and the good portion had a tensile strength of over 57 tons. Good parts were cut off for further treatment. They were annealed at 900° C. and re-rolled. The first pass of $\frac{1}{32}$ in. caused them to part again, but the "leaves" of the splay formed nearly half circles (Fig. 3). These were sheared off and the material rolled to the limit of the rolls. They did not part again, but only when rolling was commenced at the ferritic end. The hardness number of this bar was 270, but the strength had slightly increased to nearly 59 tons per sq. in.

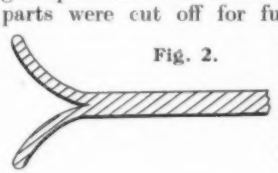


Fig. 2.

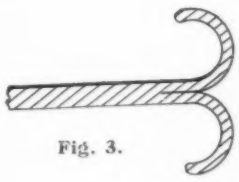


Fig. 3.

Cold-Rolled Blackheart (M.C. 1).

Three differently chemically composed bars of blackheart were next rolled. Their specific compositions were as under :—

No.	Si.	S.	P.	Mn.	TC.	Remarks.
1	0·96	0·019	0·136	0·30	2·48	Melted. Furnace not known.
2	0·71	0·165	0·081	0·20	2·65	Melted in Sesci furnace.
3	0·89	0·045	0·162	0·50	2·25	Melted in O.H. furnace.

Each was subjected to passes of $\frac{1}{64}$ in., but upon the fourth pass each one cracked in places on the surface. As rolling went on these cracks became more numerous. They appeared to occur upon the surface or upon the picture frame of ferrite, and when the core was reached cracking seemed to stop and fresh cracks developed. They widened and not lengthened. Thus the amount of cold rolling upon blackheart malleable is limited. The microscope revealed that the ferrite frame appeared to be completely disintegrated (Fig. 11). This was rather surprising when the B.E.S.A. tests are studied. It may be surmised that the intercrystalline brittleness of blackheart was present. This brittleness is removed by heating to 650° C. and quenching in water, but whether this treatment would suffice for cold rolling is a matter of experiment. The core appears to roll out without breaking, although some cracking appears just within it (Fig. 12). The frame hardens more than that of whiteheart. With eight passes of $\frac{1}{64}$ in. the hardness number is 170, but with the same number of passes of $\frac{1}{32}$ in.

1 "Hot and Cold Working of Malleable Cast Iron." By J. V. Murray. Vol. xvii. No. 99. Pp. 85–7.

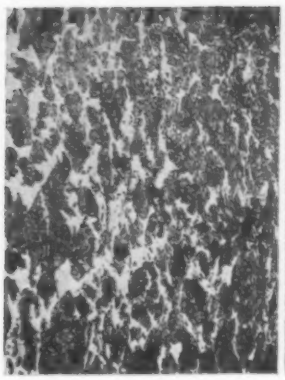


Fig. 5.—Edge of No. 1 bar as rolled. ×100

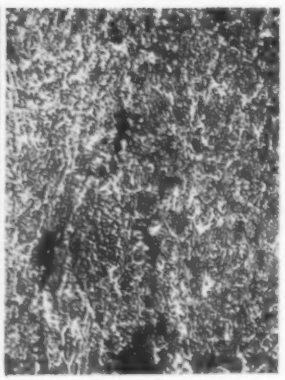


Fig. 6.—Centre of No. 1 bar as rolled. ×100

upon whiteheart the hardness number is the same. Further research is necessary in order to determine the reasons of the superiority of whiteheart ferrite when compared with the picture-frame of ferrite in the blackheart. A further test was made with a bar of smaller dimensions—i.e., $\frac{1}{2}$ in. section. This bar also broke on the fourth pass of $\frac{1}{0\cdot4}$ in. and confirmed the previous result. The ferrite disintegrates upon severe cold work, such as rolling, and is ruined. This confirms Sheppard's statement that "whiteheart is more malleable than blackheart," but it is only in the ferrite. Obviously, a core of pearlite would not be malleable, but when annealed to a purely ferritic condition then the malleability is obvious. The author has in his possession a test-bar of ferritic quality which has had a double knot tied cold in it.

The qualities of whiteheart ferritic were next tested by cold-drawing through dies. Several bars were cast with tangs like a knife or fork. These were annealed for the same periods and at the same temperatures as previously described. The shape of the bars was as Fig. 4. The tang was dressed to requirements.

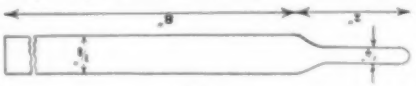


Fig. 4.

COLD-ROLLED M.C.I.
EFFECT OF ROLLING UPON MALLEABLE CAST IRON.

Bar.	Treatment.	Condition.	Brinell H. No.	T.S. Tons per Sq. In.	Remarks.
A 1	9 passes $\frac{1}{20}$ in., and 4 of $\frac{1}{40}$ in.	As received	187	39·0	Cracks appeared.
B 1	Do.	Annealed after rolling.	130	31·0	Much softer.
C 2	8 passes $\frac{1}{20}$ in. only...	As received	170	37·5	Hardens.
D 2	Nil	Annealed at 680° C.	113	31·25	Softer.
E 2	Nil	Annealed at 900° C.	—	—	Softer.
F 2	4 passes $\frac{1}{20}$ in. and 1 $\frac{1}{120}$ in.	Annealed at 680° C.	340	74·0	Parted almost in two.
G 2	4 passes $\frac{1}{20}$ in., 1 $\frac{1}{40}$ in., and a further 4 of $\frac{1}{120}$ in.	Annealed at 900° C.	402	88·0	Very good results limit of rolls.
H 2	8 in. × 1 in. × $\frac{1}{4}$ in. as received, 9 passes $\frac{1}{24}$ in.	As received	277	58·0	Splayed out.
J 2	One pass $\frac{1}{32}$ in.	Annealed at 900° C.	270	59·0	Splayed out again
B.H.	8 passes of $\frac{1}{24}$ in.	As received	170	37·5	Cracked on 4th pass. Hardens.
B.H. 2	9 passes of $\frac{1}{24}$ in.....	As received	187	39·0	Do.
B.H. 3	4 passes of $\frac{1}{32}$ in.....	As received	—	—	Do.

M.C.I. Wire

Cold-drawn Malleable Cast Iron.—Whilst, at the moment, this appears to be an academic curiosity, the toughness of M.C.I. (whiteheart) does not appear to be commensurate with the routine tensile test. With a 57½% reduction in area, with a few passes through the dies, the wire was fractured. In this case the structure retains its identity with a ferritic outside zone and a centre of pearlite, ferrite, and a few nodules of carbon. No doubt had a simple anneal been decided upon at about 50% reduction the

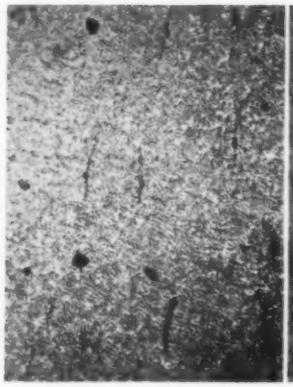
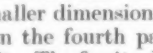


Fig. 7.—Edge of No. 1 bar as rolled and annealed. ×100

Fig. 8.—Centre of No. 1 bar as rolled and annealed at 900° C. ×100

sample could have been drawn down *ad lib* until the ferrite and the pearlite were all intermixed. The outside was bright, but covered with a series of waves, as shown in sketch.  The oxidised skin draws out just the same, and the demarcised lines do not break. The strains involved in wire-drawing are great, and whiteheart iron can be well recommended for such service as high-tension electrical work, since these strains are similar, but with insulation or the casting acting as a die. Many bars were drawn into wire, but as this forms part of other research work, the complete details are not discussed here, but it can be drawn out without fracture, and in doing so it hardens and becomes stronger, but the ferrite area retains its identity to a marked degree when compared with that which has been cold-rolled. The microphotographs are shown in Figs. 19, 20, and 21.

Hot-Worked Malleable: Further Experiments in Hot Work

Further experiments were next conducted upon Ryder swaging machines, and upon a steam hammer. Success can only be achieved by careful control of the temperature. Whiteheart M.C.I. can be forged fairly easily upon Ryder machines, but the metal must be heated correctly and not too hot. It must not be heated so hot as a mild or medium carbon steel when severe reductions are to be made, otherwise if heating, say, to incipient melting point, any combined carbon is decomposed and deposited as graphite as in the microphotograph (Fig. 13). This, of course, has a weakening effect. It is better practice to have two operations with a lower temperature and so retain the strength. The microphotographs show two levers which had been

Fig. 9.—Edge of bar G 2 rolled to limit of rolls and annealed. ×100

Fig. 10.—Centre of bar G 2 rolled to limit of rolls and annealed. ×100

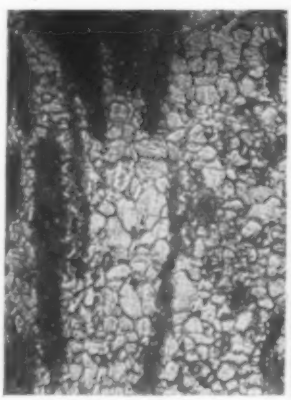


Fig. 11.—Edge of black-heart bar showing disintegration of the ferrite. ×100

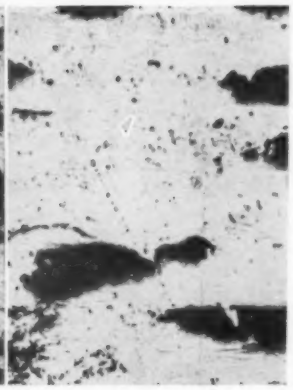


Fig. 12.—Centre of black-heart bar showing signs of cracking. ×100

forged down on the Ryder. If overheated, free cementite reforms in the sample (Fig. 14). If further overheated, free graphite is deposited in the centre and the continual swaging operation results in a cracked centre. It cannot be forged in a haphazard manner like steel, but must be controlled during the heating operation. The ferrite forms a halo round the bar. The bars were 1¼ in. in section, and were drawn down to ½ in. in one operation.

Effect of Hot Forging.—This has the effect of breaking up the dendritic structure, which persists in spite of all heat-treatments. The grain is refined, the as-cast condition is removed, and any free cementite may be pushed into small areas of their own. It is well known that a square or rectangular cast specimen is never as strong as a sample cast in a circular shape. The following table gives some figures which were carried out upon such sections. In the as-cast and annealed condition bars were made for " bends " to B.E.S.A., but were broken by a tensile test instead of a bend.

EFFECT OF SHAPE AND FORGING UPON M.C.I. BARS.

Bar No.	Shape.	Load Tons.	Tons/Sq. In. Ultra Stress.	Elongation % on 2 in.	Remarks.
1	Rectangular	5·7	25·6	3·12	Forged from a round cast bar and normalised.
2	,,	5·7	25·6	3·12	
3	,,	6·5	29·2	3·12	As above, but in the as-worked condition.
4	,,	6·7	29·8	3·12	
5	,,	8·0	21·3	3·12	Cast rectangular.
6	,,	8·0	21·3	3·12	
7	Round	5·0	20·0	9·37	
8	,,	5·0	20·0	9·37	

These bars (1, 2, 3, 4) were cast round and were forged on an anvil by a blacksmith, but were all annealed together.

Hot Swaging.—The structural effects are shown in Figs. 15, 16, 17, and 18. In the as-worked condition the peel

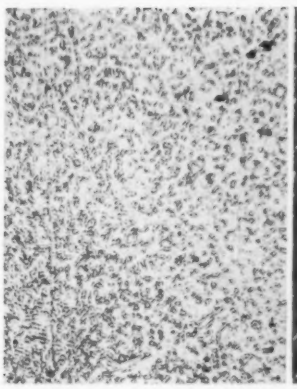


Fig. 15.—Outer zone after hot forging : note disappearance of peel. ×100

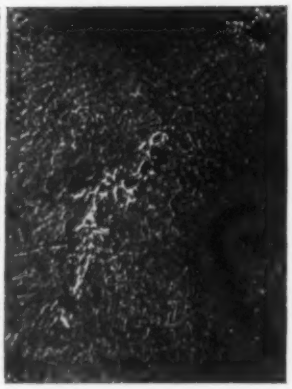


Fig. 16.—Centre after hot forging : note pools of free cementite, ferrite being thrust into centre. ×100

formation or skin effect has been effaced. The ferrite has been pushed between the pearlite, whilst the free cementite is not entirely obliterated. Forging may have this effect.

After normalising the peel reappears. The peel cannot be an oxide ; it is a zone of carbide which dissolves at high temperature. The free cementite islands tend to dissolve into the pearlite. As hot-worked, free cementite, troostite,

Fig. 17.—As in Fig. 15, but normalised : note the peel returns. ×100

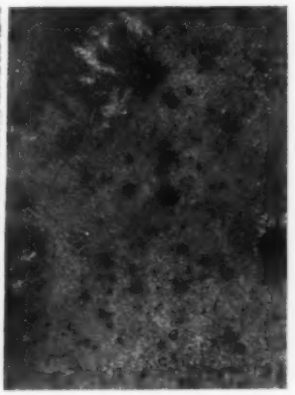


Fig. 18.—As in Fig. 16, but normalised, showing diffused carbon. ×100

sorbite, and pearlite are sharply demarcated, but the annealed condition tends to allow these to distribute themselves. There is an increased strength of 10 tons per sq. in., which is reduced to 5 tons per sq. in. through

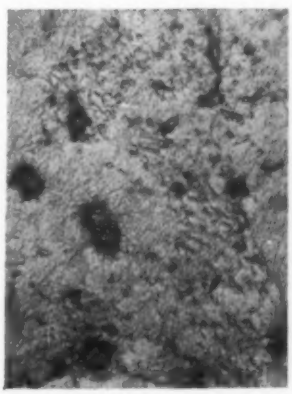
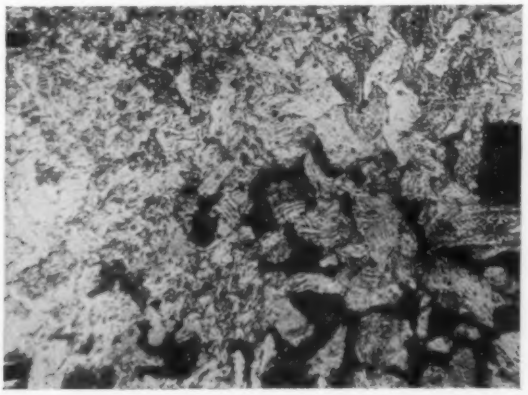


Fig. 13.—Malleable worked by Ryder hammer, overheated, developed crack in centre. × 100

Fig. 14.—Malleable, worked by Ryder hammer, showing veins of cementite and a little nodular carbon. × 400

Fig. 19.—Cold drawn into wire, the cross section being reduced 57½% ; note junction between centre and ferritic outer zone. ×100



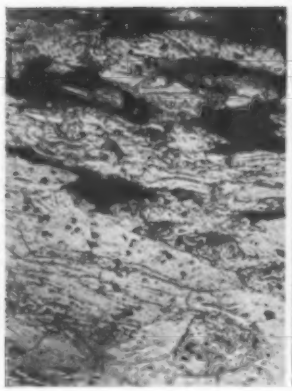


Fig. 20.—Outer zone of cold-drawn specimen. ×100

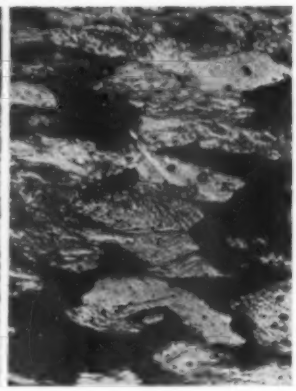


Fig. 21.—Centre of cold-drawn specimen. ×100

normalising. Tiny nodules of carbon appear to make themselves apparent once more. This would be where the carbide is supersaturated.

Applications of Hot- and Cold-Working

In most cases a forged steel article, especially a drop or a machine forging, is a solid mass of metal, requiring quite a lot of machining, which is very expensive. Sufficient has been stated to show that a casting can be made in whiteheart malleable, all difficult machining cored out, and hot- or cold-work applied to the other portion, so that one part can be forged, making this very strong. The cored part may be case-hardened or heat-treated, thus bringing it up to or beyond the strength of the forged part. Levers of excavators, cranes, or any handles of length are typical of hot-worked cored articles. A very fine finish can be obtained by finishing the forging at a temperature below the critical range. It is a well-known established fact that a round cast article is stronger than a square casting. By casting the shape round and forging it square a much stronger article is obtained. The columnar structure is broken up and refined, and an increase of strength up to 10 tons results.

Sufficient has been said to show that whiteheart malleable can be improved greatly by hot- or cold-work. A new technique will be developed upon the scientific side for its control, and the material will command increased respect from engineers on account of its cheapness and improved physical properties.

The author wishes to thank the Staffs County Education Committee for the use of rolling mill, furnaces, and microscopical appliances at the County Technical College, Wednesbury, and especially Mr. W. Plant, B.Sc., for assistance in the rolling mill in connection with this work.

Spectrochemical Analysis in 1938

THIS is a companion publication to "Spectrochemical Abstracts, 1933-1938," and includes a review of the progress in spectrochemical analysis from 1933 to 1937. The chapter on quantitative spectrochemical analysis with the microphotometer is decidedly informative, its application in the analysis of magnesium alloys being cited. The theory of the recommended method, with necessary mathematical data, is equally commendable. The works analyst will find much of interest also in the section discussing the causes of discrepancies between chemical and spectrochemical analysis; there is a short chapter on sparking circuits, and the student will agree that the 30-page section on the elements of atomic spectrum theory is of strong practical and academic value.

By F. Twyman, F.R.S. Adam Hilger, Ltd., London. 4s. 4d. net.

Preparation of Metal Surfaces for Paint Protection

THE protection of metal surfaces by paint is largely dependent upon the preparation and pre-painting condition of that surface. This subject, of the pre-treatment of metal surfaces for painting, was analysed recently by F. N. Speller,* in which he showed that proper preparation of the surface is of fundamental importance if the best protection of iron and steel is to be obtained.

This preparation includes the removal of all foreign matter, other than that tightly bonded to the metal, and that the surface should not only be dry, but preferably warmed, whilst also being free from any reactive substances immediately prior to the application of paint or priming coat. The advantages of de-scaling were discussed, but the author concluded that, as a rule, the most desirable preparation of steel surfaces is complete de-scaling, followed by phosphating or similar chemical treatment. In regard to the latter point, the significance of the surface film formed by reaction of the metal with its environment was emphasised, in that these surface films when thoroughly bonded, stable and absorptive usually offer a better surface than the metal itself. The three major considerations are the bond of a surface film to the metal, the cohesive strength of the film, and the adhesion between the paint and surface film.

Phosphated surfaces, it was shown, generally give good paint adherence, and the more adherent film on copper steel makes paint hold better and last longer than on plain steel under most conditions. It was mentioned that the corrosion committee of the British Iron and Steel Institute have taken a rather definite stand in favour of removing all mill scale, but it is argued that the bond of mill scale to the metal varies considerably on the same piece of steel, and in some cases the strength of the bond may amount to several thousands of pounds to the square inch, before weathering. Another factor is, however, introduced—where moisture is present the scale is cathodic to the metal by about 0·25 volt, and eventual loosening of the scale results from the corrosion under the scale.

The mild corrosion-inhibiting qualities of red and blue lead are stated to be considerably improved when used with more than 25% of zinc chromate, and addition of the sodium chromates to water greatly retards or stops the galvanic action between mill scale and steel; in the absence of mill scale, about 300 p.p.m. of dichromate will be sufficient to prevent corrosion, and the normal chromate (pH 8·5) is even more effective. A useful point is that the phosphated film formed by reaction between iron and phosphoric acid serves as a mild inhibitor and improves the adherence of paint.

The several water-inhibitive solutions which have appeared on the market in recent years for pre-treatment of metal surfaces for painting, improve adhesion and retard corrosion under the paint film; these generally contain orthophosphoric acid or chromic acid. Proper application is essential. If surfaces have not been completely de-scaled, it may be advisable to wash them with water after the reaction of the inhibitor; and if the temperature is too low, the reaction between the metal and the solution may remain incomplete, this leaving unused acid on the metal, and this acid may be trapped between the metal and the paint film, later destroying that film by reaction.

Illustrations were given that showed the great improvement resulting from the use of inhibitors applied to steel surfaces before painting, the steel plates being immersed afterwards in harbour water for about eight months. In one case the surface was weathered, scratch brushed, and painted with a phenolic primer containing 50% zinc chromate, and was given a phenolic finishing coat; in another specimen the surface was de-scaled by pickling and then given a bakelite primer and finishing coat. In both examples the inhibited surfaces showed far better resistance and much less tendency to blistering.

* Ninety-fifth meeting of the American Chemical Society.

Use of Light Alloys in Aircraft Construction

Light aluminium alloys and ultra light magnesium alloys are a great advance on other materials, and if their development coincides with the requirements of aircraft manufacturers, and production methods are in accord with the needs of aircraft construction, a great future can be guaranteed for them. This is the view of M. R. le Cœuvre, expressed in a recent lecture before the Royal Aeronautical Society. He summarised recent developments, analysed research tendencies, and endeavoured to give direction to rational and economical use of light metals in the development of aviation, the main features of which are given in this article.

LIGHT alloys now play a very important part in aircraft construction, and it is probable that they will keep their present superiority over other materials which have been in use, because manufacturers are continually adopting light alloys to the need of the day. Although there are many arguments for the use of wood and plastic materials, M. Cœuvre contends that if it is intended to speed up production and further the development of aviation by lowering costs and time of labour, one is automatically led to the judicious use of metals. Statistics have shown that by developing tools and by making use of metal construction on a large scale, it is possible to lower the working time on any unit by a considerable amount, but the form of construction must not slavishly copy that of wood.

In metal construction itself, other alloys, as well as light alloys, are the objects of constant research and improvement. Thus special steels, stainless steels, Monel metal, and other heavy alloys are competitive; gradually, their characteristics are improving, and taking into account their greater density, their strength/weight ratio can at times exceed that of light alloys. The lecture was presented in three parts: the first giving a summary of recent developments which have received the approval of industry; in the second M. Cœuvre endeavours to analyse research tendencies by considering what appears to be of immediate and direct interest to constructors; while in the final part the question of costs is discussed and an effort made to reach a rational and economical way of giving a new impulse to the development of aviation by the use of light metals.

RECENT INDUSTRIAL DEVELOPMENTS

There has been much development in the production of light alloys for use in engines. Those formerly used in the "as-cast" condition for pistons, crankcases, and cylinder heads were, in general, composed of an aluminium-copper alloy, containing about 10% copper, in which the tensile strength was of the order of 6·5 to 7·5 tons/sq. in. at a temperature of 20° C. Their elongation and resilience was exceedingly low. To-day the alloys used for crankcases are more complex. Additional elements have improved the strength properties by enabling the use of suitable heat-treatment, raising tensile strength from 18·5 to 21 tons/sq. in. Further, the repair of crankcases which have deteriorated in service has become possible by a welding process. The characteristics of magnesium alloys also have been improved, particularly those for use at temperatures up to 300° C., by the addition of silver and cerium.

In addition to purely technical progress, advances have been made in production by the use of pressure die-casting for magnesium alloys and certain aluminium alloys used for carburettor bodies, and by press-forging certain parts, such as pistons. In such cases as pistons the hardness obtained by heat-treatment is not permanent at the temperature at which they work, since this corresponds to the annealing temperature. These parts require no further machining when they come from the press, and they have a hard, superficial skin formed over the surfaces. Certain large parts are successfully subjected to pressure during solidification, a process which is claimed to produce a finer grain and to improve the characteristics of the alloy.

The use of light alloys in the construction of the airframes generally concerns extruded sections for structural members, rolled sections, mainly sheet and strip, stampings in aluminium and magnesium alloys and magnesium alloy castings. M. Cœuvre predicts that aeronautical construction will tend more and more towards the use of sheet and strip. It is the most economical means of using the material since it avoids unnecessary scrap, the metal keeps its superficial skin, its storage in rolls is the least cumbersome, while no finished part has greater safety than a piece of formed or welded sheet without discontinuities. The use of extrusions is equally advantageous, while in order to reduce the number of different sizes and shapes as much as possible tubes may offer a simple solution.

In forming light alloys, it is possible to achieve very accurate production, suitable for parts required in aeronautical engineering, without the use of costly steel dies. The steel dies can be replaced by those made in zinc, into which the sheet is thrust by a rubber pad. In case of modification, the material can be remelted and used for the new die. Magnesium alloy dies are also used, and also steel-faced wooden dies.

In the assembly and mounting of light alloys there is still plenty of room for development. High-duty alloys, such as Duralumin, cannot be welded, assembly being done by riveting. A technique of riveting light alloys has been evolved in the course of the last few years, in which riveting up to $\frac{7}{32}$in. is generally done cold. The rivets are used in the normal state, and the snap heads are cold-hammered. Above $\frac{5}{32}$ in. in diameter the rivets are used as soon as possible after quenching in order to take advantage of the consequent malleability of the metal. With a view to prolonging this malleability characteristic, the rivets may be kept at a temperature of — 10° C., the age hardening is then interrupted and only takes place when the metal is allowed to return to normal temperature.

Aluminium-Magnesium Light Alloys

The advent of aluminium-magnesium alloys has opened new possibilities to constructors. These alloys have two important advantages: they are weldable and non-corrodible by sea-water. These properties may be attributed to their greater homogeneity of structure and the complete absence of copper. Industrially, these alloys may be viewed from two aspects: those containing less than 7% of magnesium and those containing from 7 to 9% magnesium. The ultimate tensile stress of the former is of the order of 20–23 tons/sq. in., with elongation of the order of 25%. These properties are obtained after annealing, the metal being improved by heat-treatment. Forming, bending, and drawing are done cold on annealed metal, in which condition it is amenable to deep drawing without damage. The metal may also be worked hot, since its properties are not due to quenching, and as soon as the metal cools to the surrounding temperature, the original properties of the annealed metal return. Autogeneous

welding presents no difficulties, but an appropriate flux must be used. Every trace of the flux, however, must be removed after welding, otherwise there is risk of corrosion.

The properties of the alloys containing from 7 to 9% of magnesium resemble very closely those of the well-known alloys. The ultimate tensile stress is of the order of 27 tons/sq. in., with elongation of the order of 25%, but these properties are obtained by both heat-treatment and quenching. Quenching is done from a temperature of about 450° C. The metal is brittle at temperatures between 150° to 350° C., and it is better to prevent the alloy remaining for long in this temperature zone. This is a serious inconvenience to the constructor, who may want to use such a temperature in order to bake certain enamels or varnishes. Forging and drawing operations may be done cold on quenched metal, but they are preferably done hot. A final operation of quenching gives the highest qualities to the material. Autogeneous welding is quite convenient, but the strength of the welded joint is definitely inferior to welded joints of base metal. It appears that aluminium-magnesium alloys are capable of great improvement by some additions, notably titanium, even in very small proportions. In this case the magnesium content can be increased with advantage. Improved alloys of this type, however, have not yet been developed beyond the laboratory scale up to the present. It is claimed that the properties of stability and weldability would be retained.

Magnesium-Rich Alloys

The alloys of magnesium are used in the cast condition in various members of the landing gear, wheels, equipment, and various supports. They are employed as sheet for the construction of tanks and welded parts in general. The strength values obtained on the sheets can be as much as 18 to 20·5 tons/sq. in., with 10 to 14% elongation. The construction and repairing of these alloys are considerably simplified by ease of welding, which makes the alloys valuable to designers. It is important to remove all traces of flux after welding.

The possibilities of application of the alloys of magnesium in aircraft construction are limited to a certain extent by their sensitivity to the corrosive action of moisture, sea-water, and marine atmosphere. To remedy this, numerous investigations have been pursued, and users are informed of a certain number of measures to be taken to ensure for the material good stability. A good protective treatment applied just after leaving the mould, in the case of castings, and just after leaving the rolling mill, in the case of sheet, is necessary and adequate for guaranteeing stability in the subsequent treatments.

These protective treatments are achieved by immersion in boiling liquids; designers, however, prefer cold methods. Reference was made to interesting methods which have been studied in this country, notably those of Lews and Evans (cold solutions) and those of Sutton and Le Brocq, as well as the method of Bengough and Whitby, using arsenious acid. Apart from these dipping treatments, activity has been displayed recently in various countries in connection with processes of anodic protection. A certain number of these have proved efficacious, and have taken their place in industry. From the standpoint of efficiency there is little to choose between electrolytic treatment and the dichromate dipping treatment. It must, of course, be borne in mind that in the course of successive manipulations, such as machining, forging, etc., part of the protective film may be removed; it is necessary to maintain the protection. The same applies when sheets have been assembled by welding, the protective film has disappeared in the vicinity of the seam, which must be renewed immediately. Surfaces prepared with protective films are further treated with lacquer or enamel finishes, baked or unbaked, according to the finish required. Excellent finishes of this character have been produced and assist in giving good stability to material.

Light Alloys in the Construction of Seaplane Hulls and Floats

For the construction of the hulls and floats of seaplanes, the assemblies must not only be strong but also watertight. In the riveted assemblies the water-tightness is achieved by interposing between the assembled elements plastic joints, or simply strips of strong paper, insulating the sheets by two coats of bituminous paint or zinc white paint. In time, under the action of variations of temperature or under the action of vibrations, the joints dry up and contract. The grip of the rivets becomes unreliable, the water-tightness is not certain, corrosive sea-water penetrates the interior of the hull, remains there and causes disintegration.

The Uses of Vedal or Alclad.—Vedal or Alclad have the advantage of standing up better to sea-water than do alloys of the Duralumin type, hence the favourable position which they occupy in the construction of hulls and floats. It is, however, necessary to mention that the Vedal assembly cannot be achieved without the use of rivets of the Duralumin type of alloy. Due to this fact, there arises between the rivet heads and the main sheeting heterogeneities which give rise to electrolytic couples, which prejudice the corrosion resistance of the assembly. Research on water-tightness points to the employment, as in the above case, to plastic joints. The need for stability necessitates the application of insulating and protective surface treatments.

The appearance of the aluminium-magnesium alloys can effectively facilitate the task of designers of hulls and floats, since autogenous welding gives a first-rate solution of the problem of water-tightness, while electric resistance welding, although it has given rise to misapprehensions, seems capable of giving satisfactory results when the conditions have been studied. The problem of repairing is also considerably simplified by it.

Electrolytic Effects which Arise.—Inasmuch as the welding processes have not been made general, it is not apparent how perfectly homogeneous assemblies can be obtained. The material of which the rivets are made cannot be absolutely the same as that of the assembled sheets. Moreover, the exigencies of construction sometimes require assembling of elements of different nature—e.g., the fixing of a steel shoe to a light alloy float, or of a reinforcing ring to a light alloy hull. Whatever precautions are taken to assure the electrical insulation of the junction, there is no doubt that the manufacturing processes give rise to circumstances which cause corrosion.

In order to avoid these situations, it has been suggested that elements of metals less noble than those in contact should be inserted at various points. In the special case of a steel-light alloy junction, zinc and cadmium are suitable for this purpose. The electrolytic actions so produced lead to the progressive destruction of the additional element while giving the joint a protection as efficient as it is vigorous, and which admirably satisfies the requirements. The metal spraying process is particularly suitable for remedying this defect. By means of this it is not only possible to fix the initial masses, but it is remarkably easy to maintain them.

Conclusions

In conclusion, it is obvious from a survey of the above field that a good technique has actually been established for using light alloys, and the precautions which may be taken for their successful utilisation, even in the sea. The appearance of weldable light alloys with good resistance to sea-water is such as to facilitate to a great extent the task of the designers, allow simplifications in the manufacturing processes, give a greater homogeneity in the assemblies, and, finally, increase the potentialities of production. It is, however, necessary to mention that the alloys which satisfy the requirements of weldability and stability have properties much inferior to the better-known light alloys.

The designer willingly accepts the new advantages, but is not willing to "pay" for them by sacrificing the high properties. He requires of metallurgists that they should make the necessary effort to procure the ideal alloy which will embrace all these advantages. It is satisfactory to report an appreciable improvement in the fatigue limit in the course of deductions made during fabrication. Since this property is so important from the point of view of stability and safety, it is essential for the progress to continue and for the aluminium-magnesium alloys to be able to share in this improvement.

It is pleasant to think of simplifying production methods, but before embarking upon a new technique it is desirable for them to be studied first in detail, and that the technique of the electric welding processes should be put upon a secure experimental basis. The best results obtained are those concerned with the stability of the alloys which give satisfaction in this respect, but the question arises as to whether or not the passivity conferred upon the alloys could not be made more complete by the introduction of certain additional elements, and whether the principles established for the light alloys could not be extended with success to magnesium-rich alloys.

DIRECTIONS IN WHICH RESEARCH WILL MOVE

The Improvement of the Properties of Aluminium-Magnesium Alloys and in Particular the Fatigue Limit

Investigations are actually being pursued to discover how to improve the mechanical properties while retaining the welding properties and stability unchanged. MM. Canac and Segol have, by making special additions, been able to obtain in the laboratory alloys with very much higher properties. The use of base metals of very high purity can contribute to a great extent in raising the fatigue limits. A very remarkable degree of purity can be obtained by using Hoope's cells for aluminium and the sublimation processes invented by MM. Chaudron and Herenguel in the case of magnesium. The liberation of gases and the prevention of blowholes are also factors which can contribute to some extent to the raising of the fatigue limits.

The Establishment of a Good Technique of Electric Welding.—The spot or seam electric welding of light alloys is a difficult problem. The difficulties arise from :—

(1) The high electrical and thermal conductivities of the metal. These tend to limit the passage of current to a very short time and to the employment of currents at very high tension.

The order of these data is as follows :—

Density .. .. 50,000 amperes.
Time ..... $\frac{1}{10}$ - $\frac{1}{1000}$ sec.

However, according to Hibert,[1] good results would have been obtained with considerably different data :—

Density..... ..... 5,000 to 30,000 amperes.
Time ..... 10 periods (or about $\frac{1}{5}$ sec.).

(2) The relatively low fusion point of the metal.

(3) The presence of an oxide film between the joined ends.

(4) Corrosion hazards caused by the use of copper electrodes and the necessity to change these electrodes very frequently.

In this respect, tests carried out with chromium electrodes seem to give more satisfactory results. The pressure of the electrodes on the pieces is a very important factor which also has its effects upon the other properties. If it is excessive, it produces on the surface a local cold-working effect which can become independently a cause of corrosion. If, however, it is too low, the point extends over all the thickness of the sheet, and forms a series of pores and cracks. Generally speaking, the results obtained with the "aluminium-magnesium" alloys are better than those with the "Duralumin" type alloys.

The behaviour of assemblies under dynamic stresses and vibrations has been the subject of very many researches. Particular reference is made to the comparative tests on welded test-pieces and riveted test-pieces carried out at the Bayerische Flugzeugwerk[2] ; the tests performed in the laboratories of the Establissement d'Experiences techniques d'Issy les Moulineaux (Mlle. Doussin) ; and the tests carried out in the laboratories of the Société du Duralumin. The doubts which might have been entertained *a priori* on the behaviour of assemblies when subjected to vibrations can apparently be dispelled.

The very important part played by the current density is noteworthy. For a convenient density, the actual weld is completely internal. The outside surface cooled by the electrodes never reaches the fusion point. The melted part solidifies in a sort of crucible made up of the non-melted parts of the sheet. If the density is very low, the melted zone is slightly expanded or suffers a loss in mechanical strength. If, on the other hand, it is too high, the crucible is broken and the molten metal reaches the surface. The electrodes are damaged and corrosion results. Systematic macrographic tests performed on sheets of almasilium 1 mm. thick have demonstrated very clearly the effects of the current density on the shape and size of the joints.

Heat-treatment Following Electric Welding of Aluminium-magnesium Alloys.—From the viewpoint of electric welding, the use of aluminium-magnesium alloys has a marked advantage over that of alloys of the Duralumin type. The part of the metal, the structure of which has been altered by the welding, can have its structure restored by heat-treatment. In this way one can hope to obtain a more uniform structure in the complete assembly, and increase the individual mechanical strength of each p int, as well as the resistance to dynamic stresses.

The actual achievement of the treatments on the large assemblies raises other problems which have, to the author's knowledge, not yet been solved.

The placing of large light alloy assemblies in the heat-treatment chamber has always been avoided, because holding them at a temperature higher than 150° C. involves a general lowering of the mechanical properties. The employment of stoving lacquers, particularly hot polymerised bakelite resins, has always been avoided (due to this fact) in the protection of high-strength members. This danger does not exist for the aluminium-magnesium alloys of low-magnesium content. In the case of alloys of 8% magnesium, it has been shown that a fragile zone exists between 150° and 350° C., and it is necessary to avoid keeping the alloy too long in this section.

Industrially, the two operations, heat-treatment of the assembly and stoving after protection, could be effected simultaneously in the course of one period in the furnace. One would thus be inclined to produce, for aircraft construction, stoving installations, similar to those which exist for automobile construction. Attempts to apply aluminium-magnesium alloys in car construction are actually in progress. It is very obvious that if the attempts to use heat-treated resistance welded alloys give full satisfaction, the extension to aircraft construction could be made immediately.

The Water-tightness of Welded Seams.—Tests have been performed in order to obtain water-tight assemblies (floats, tanks, etc.) by seam welding. These experiments have not always given satisfaction. This question deserves to be the subject of a special experimental investigation. Although the parts are not joined at the surfaces, it should be possible in the welded seam to arrange the heating zones to a degree sufficient to assure that a continuous line is produced, and, consequently, that the weld is water-tight. The doubling of the welded seam would appear to constitute a good precautionary measure.

Objection has often been made to welding machines because they are cumbersome and stationary. It is suggested that it is the machine which should go to the metal part and not vice versa. I am glad to be able to say in this respect that the technique of welding machines has

1 Charles A. Hibert. "Spot Welding of Aircraft Materials," Weld J.B. 17, 1938.

2 F. H. Hintzen—Augsburg. "Die Elektrische Funktschweissung von Duraluminkonstruktions in Flugzeugbau." (The Electric Spot Welding of Duralumin Structures in Aircraft Construction.) Luftwissen. August, 1938.

developed considerably in the last few years, and improvements to them are being made constantly. There exist in industry portable spot-welding tongs, hydraulically driven, with double action, which have the advantage of decreasing the weight and bulk of the head. On the other hand, the cylinder motor can be mounted on a C-shaped frame. The lower electrode is fixed on a horizontal axis so that it can be counter-poised in order to remove the pieces. The transformer and the control system are separate from the tongs, but are connected to them.

Welding Control.—The radiographic control over the welds is a process which has been applied for a long time. By a suitable filtering of the rays and an appropriate choice of the incidence to be given to the exploring rays, it is possible to show up very slight differences on the image and expose extremely fine flaws. It is to be noted that the generating units are becoming more and more portable, and led themselves more and more to the control of large pieces, even on the factory scale of production.

Research on Stability in Sea-water.—Research on automatically protected alloys—i.e., those resistant to corrosion without any surface treatment—exposed to sea-water has been pursued with increasing enthusiasm in every country for more than 15 years. The work of Dr. Evans, Professor Bengough, Sutton, and other eminent British scientists, has thrown a particularly vivid light on the question of corrosion. In France, a Research Commission was established in 1925, with the respected expert, Inspector-General Grard as president, to study specially the questions of corrosion (M. Grard died last year). The work of the Commission is actually carried out under the direction of President Caqnot. The work of this Commission, in which eminent savants and engineers participate, is published periodically, and shows the evolution of the ideas on the subject.

Aluminium is not a noble metal. It occupies in Nernst's Scale a very low position, between iron and zinc, but it is possible to confer an " acquired nobility " on aluminium and its alloys. By introducing into the base metal, even in traces, suitably chosen constituents the particles of which are very finely divided, even if they are less noble than the base metal, it is possible to obtain on the surface a continuous film which confers passivity on it in a given reagent, in this case sea-water. The formation of this film can be accelerated by introducing an applied electromotive force, such as operates when the part is subjected to anodic treatment. In cases of local damage, the protective film reforms itself automatically when the alloy is immersed in the reagent for which it was developed. The composition of the alloy can be chosen in such a manner that the film, by its nature, thickness and constitution has adhesive properties, impermeability, and the electrical resistance necessary to assure adequate protection of the coated metal.

In order to establish the relationship between the properties of the protective coating and the structure of the metal, several correlated ideas are involved.

(1) The necessity for having the base metals extra pure, so the simple, well-defined alloys can be formed, in which the additional elements can be easily identified.

(2) The Laws of Pilling and Bedford enable us to discover in advance, from the respective densities of the metal and its oxide, whether or not the oxide film will be protective and whether or not there will be contraction, porosity, discontinuity, or lack of efficiency.

(3) The need to clean and polish the base metal : it is necessary to take note of the topography of the metal underneath—i.e., its state of polish—which plays an important part in the formation of the film. The latter is adherent in proportion as the primary structure of the recently alloyed elements is close. The " Solex " micrometer and M. Canac's diffusionmeter could find a wide and profitable field of investigation here.

(4) The necessity for measuring precisely the thickness of film required. In general, it has been discovered that thin coatings—e.g., invisible films, of which the thickness is less than the wave-length of visible light rays—are the most flexible, most adhesive, and, consequently, the most protective. The mechanical properties of the film so formed, with or without the bringing into play of external E.M.F.'s, are still little known.

The suppleness—i.e., the power of the films to undergo important deformations without rupture—can play a very important role in the corrosion fatigue fracture phenomena. One could conceive that if at each reversal there is fracture in the protective film, when the frequency of alternation is so large that the film has not time to rebuild itself, corrosion will rapidly increase the crack which the rupture causes.

The velocity of re-formation of the film at fracture is thus yet another factor operating, and one particularly interesting to study. A relationship should exist between this speed and the resistance to corrosion fatigue. This speed could itself be a function of the state of division (more or less large) of the addition elements in the base metal. This simple treatment gives an idea of the extent of the field of investigation which is open to research.

FUTURE DEVELOPMENTS IN THE USE OF LIGHT ALLOYS IN AIRCRAFT CONSTRUCTION

The preceding considerations lead to the conclusion that the producers of light alloys should make the necessary efforts in order to be able to put at the disposal of the users alloys of high strength, which acquire their maximum mechanical properties without quenching heat-treatment, by simple annealing, and possessing good welding properties and resistance to sea-water. With such alloys the users could have a chance to equip their factories for intensive production. In these factories the drawing presses and the portable welding machines would be used in the main part of the fabrication. It should be mentioned that the initiation of mass production would necessitate preliminary investigations with close collaboration between the laboratory, the factory, and the research department.

The professional education of the executive personnel is one of the factors, and not the least important, of those to be examined. The work calls for work from welders and metal workers that has nothing in common with that which is required from copper braziers. Since the technique is not identical for each alloy used, measures would be taken to avoid confusion in the minds of the personnel. With these reservations, one could predict that the introduction of the alloys and the new processes would bring a new lease of life to the light metal industry, to the very great advantages of the aerial navigation of to-morrow.

Sir Robert Mond

WE regret to announce the death of Sir Robert Mond, who died in Paris on October 22 last. During his early years Sir Robert collaborated with his father, Dr. Ludwig Mond, in discovering the gaseous metallic compound, nickel carbonyl, and in investigating its properties. It will be remembered that this work led to the Mond Carbonyl Process of refining nickel. After the death of Dr. Ludwig Mond, in 1910, Sir Robert continued his studies of the metallic carbonyls, and he later perfected methods for the industrial production of iron-carbonyl.

In addition to his metallurgical researches, Sir Robert possessed the rare attribute of a trained scientific approach to the problems of everyday life. His thirst for accurate knowledge was immense, and he applied his talents to the widest possible range of arts and sciences. He made a particular study of agriculture, and, in his laboratory, bacteriological and chemical examinations on all the various products of his farm were continuously carried out. Almost every phase of chemistry, physics and electromagnetic phenomenon attracted him

His many personal kindnesses and his tireless encouragement of young research and industrial workers will make his loss keenly felt in a wide sphere of scientific activity.

The Measurement of Temperature*

By E. C. Rollason, M.Sc.

In the last issue the author stressed the importance of the accurate measurement of temperature in many industrial operations and discussed the underlying principles on which the common temperature-measuring instruments are based; in this article particular reference is made to radiation and optical pyrometers.

Radiation and Optical Pyrometers

For measuring high temperatures it becomes necessary to use an instrument which need not be in contact with the hot body. Such pyrometers depend on the radiant energy emitted by the hot body, and obey certain laws, which apply to a perfect "*black body.*" A "black body" may be defined as one absorbing all radiations falling on it, without loss by reflection or transmission. The radiation from the interior of a chamber at uniform temperature approaches closely to the ideal conditions. On the other hand, only a fraction of the theoretical energy is received from a body in the *open*, and this fraction (always less than unity) is called the *emissivity*, which depends upon (*a*) wave length, (*b*) temperature of surface, (*c*) character of surface. A few values are given in the table :—

EMISSIVITY OF SURFACES FOR RED LIGHT (WAVE LENGTH = 0·65 μ).

Silver	0·07	Iron	0·37
Copper, solid	0·11	Iron oxide, 800° C. ..	0·98
,, liquid	0·15	,, 1,200° C. ..	0·92
Cuprous oxide	0·70		

For bodies in the open corrections have to be made.

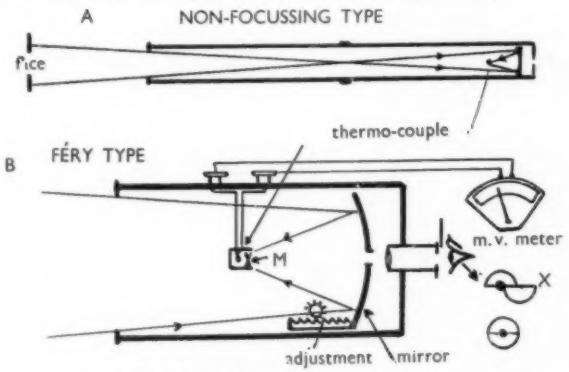


Fig. 5.—Radiation pyrometers.

The *radiation* pyrometers, used under "black body" conditions, are subject to the *Stefan-Boltzmann* Law, which may be stated as "an increase of 1% in the absolute temperature of the radiating body results in an increase of 4% in the energy emitted." Stated mathematically, the law is—

$$E = K (T^4 - T_o^4)$$

where $K = 1{\cdot}34 \times 10^{-12}$ calories per sq. cm. per second. E is total energy radiated by body at absolute temperature T to surroundings at absolute temperature T_o. Since T_o is small compared with T we can write—

$$E = KT^4$$

For bodies in the *open*, we can use the formula to find true temperature T :

$$E = KeT^4 = KS^4 \text{ or } T = \frac{S}{\sqrt[4]{e}}$$

where *e* is total emissivity and S is apparent temperature indicated by pyrometer. For example, the instrument reads 900° C. when sighted on iron ; in the open the true absolute temperature is

$$T = \frac{900 + 273}{\sqrt[4]{0{\cdot}37}} = 1{,}504° \text{ absolute or } 1{,}231° \text{ C.}$$

*Continued from page 205, October, 1938, METALLURGIA.

Most of the radiation pyrometers use either a lens or a mirror to concentrate the heat rays emitted by the hot body on to a small thermocouple, and the E.M.F. developed is measured by a calibrated millivoltmeter, ranges are usually 550° to 2,000° C., but there is really no upper limit.

Fixed focus and focusing instruments are used, as illustrated in Fig. 5a and 5b. In the *Féry* pyrometer the inclined mirrors (M) in front of the thermocouple are used to indicate when correct focus has been obtained—namely

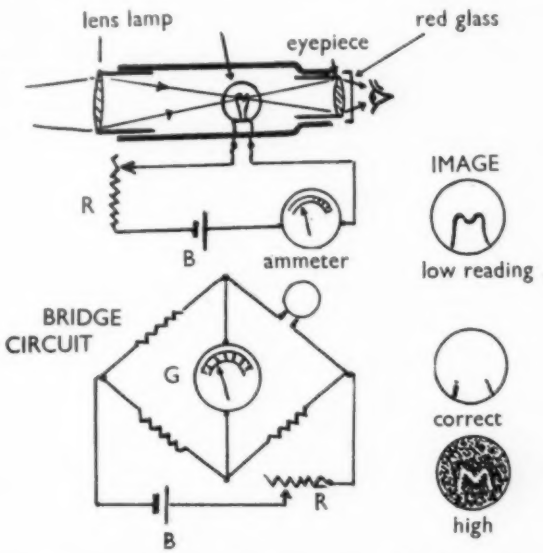


Fig. 6.—Disappearing wire pyrometer with simple and also bridge circuit.

the image of the hot body appears broken in halves when out of focus (*fg*5×).

Such radiation pyrometers require about 15 seconds to take a reading, but can be made recording in the same way as a thermoelectric pyrometer. It is essential that the image of the hot body be sufficiently large to cover the sensitive thermo-element, then the distance from the hot object is immaterial.

The *K* and *S* pocket pyrometer, however, uses a bimetal spiral with a pointer and compensating spiral. The heat rays are concentrated by a lens on to the bimetal spiral.

Optical Pyrometer

In these pyrometers the *intensity* of the *light* from the hot body is compared with the intensity of light from some standard source, and both are matched in the instrument to *one* specific wave-length, usually red light ($\mu = 0{\cdot}65$), and even a colour-blind man can do this.

The commercial instruments differ in the optical devices used to make this comparison of the two intensities of light.

In the *Wanner* pyrometer a polarising device compares the red ray from the hot body with the ray of the same wave-length from an electric lamp, the intensity of which is calibrated by an amyl acetate lamp.

In the disappearing filament pyrometer the intensity of a standard filament lamp is varied until it disappears

against light from the hot body. Fig. 6 shows the construction of a typical instrument. The lamp is placed inside a telescope, the focusing of which forms an image of the hot body in the plane of the filament. The filament and the image is viewed through the eyepiece of the telescope, adjusted to suit the operator's eye. An electric current is passed through the lamp filament, so that it is just hot enough to disappear against the image of the hot body. This current can be measured by an ammeter, and, if previously calibrated, can be used to indicate the temperature of the hot body. In the simple electric circuit using an ammeter a large portion of the scale is useless owing to the measurement of current used in heating the filament to 700° C. In some instruments the voltage drop across the lamp is measured, but the most satisfactory method of using the whole of the scale without the "set back" of the zero, is by making the lamp filament one of the arms of a Wheatstone bridge and calibrating the galvanometer in degrees, with a zero reading corresponding to about 750° C. The resistances in the circuit are so arranged that balance is obtained when the filament is at 750° C. As the filament becomes hotter its increase in resistance throws the bridge out of balance and the galvanometer pointer moves over the scale.

To cut out colour differences, a red glass filter is placed in front of the eyepiece. For temperatures above 1,400° C. an absorbing screen is placed between the hot body and the filament, so that the latter is never over-heated, but this of course necessitates recalibration.

The principle on which the instrument is based is Wien's Law, which states that the intensity of any radiation (I) of wave-length (λ) emitted from a body at an absolute temperature (T) is given by—

$$I = c\,\lambda^{-5},\ e - \frac{K}{\lambda T}$$

where c and K are constants; e is the base of Naperian logarithms.

For *non-black body* conditions—

$$\frac{1}{T} - \frac{1}{S} = \frac{\lambda \text{ Log } E}{6232}$$

where S is apparent temperature and E is the emissivity of a non-transparent material at wave-length.

The reading obtained from an object in the open will depend upon its reflecting power and its surroundings. An oxide-free metal may reflect considerable sunlight into the instrument and give a false reading.

The optical and radiation pyrometers can be calibrated against a thermocouple or the melting of a palladium wire in an electric furnace arranged to give approximately full radiation by a series of diaphragms suitably disposed. Alternatively, the instruments can be focused on the bottom of a re-entrant tube in a crucible of a pure metal, and the freezing point determined, Fig. 4D.

The photoelectric cell can also be adapted to read the temperatures of moving articles when these are visibly hot.

Mr. J. E. Hurst to Direct Work on Testing Cast Iron

AT a meeting held recently in Warsaw, Mr. J. E. Hurst, past-president of the Institute of British Foundrymen, was elected active President of the International Committee for Testing Cast Iron. This Committee, which is comprised of representatives of foundry technical associations in most European countries and the United States of America, works in conjunction with the International Association for Testing Materials. Whilst Professor Portevin, the distinguished French metallurgist, is honorary president, the future work of the Committee will be under the direction of Mr. Hurst, who was preceded in this office by Monsieur J. Leonard, of Belgium. Mr. Hurst is a director of Messrs. Sheepbridge Stokes Centrifugal Castings Co., Ltd., Sheffield, and of Messrs. Bradley and Foster, Ltd., of Darlaston, Staffs., and is one of Britain's leading authorities on the metallurgy of cast iron.

Sir Harold Carpenter, F.R.S.

SIR HAROLD CARPENTER, F.R.S., was presented with the Honorary Membership of the American Institute of Mining and Metallurgical Engineers at a luncheon, recently given in his honour in the Abraham Lincoln Room at the Savoy Hotel, which was attended by a number of the most-distinguished representatives of the British metallurgical world, both academic and industrial. The award was made to Sir Harold, who is Professor of Metallurgy at the Royal School of Mines, in recognition of his distinguished achievements in the field of metallurgy as an investigator, teacher, administrator and organiser and director of research.

Mr. D. Owen Evans, M.P., who occupied the chair, said it was fitting that the American Institute had deputed Dr. John F. Thompson (Executive vice-president of the International Nickel Company of Canada Limited) to convey the award to Sir Harold Carpenter. In making the award, Dr. Thompson said that in a gathering of this kind, consisting of friends and colleagues of the recipient, it would be superfluous for him to refer to the attainments of Sir Harold Carpenter. There were two types of men who contributed to the achievement of mining and metallurgy: those who devoted their lives to research and to broadening knowledge, and those men who devoted their lives to passing on the torch to the men who were to follow on, teaching students and preparing them for their careers. In Sir Harold Carpenter they had a man who had done those two things, and it was therefore fitting that the Board of Directors of the American Institute had selected such a man for the honour which he had the pleasure of awarding on their behalf.

In responding, Sir Harold Carpenter thought it particularly appropriate, as symbolising the award received by him from America, that the function should take place in the Abraham Lincoln Room of the Savoy Hotel, and he thanked Dr. Thompson for arranging the luncheon. He was very appreciative, indeed, of the honour which the American Institute had conferred upon him. So much of his work had been carried out in association with others that he wished to thank those who had helped him in his work in one way or another and enabled him to win this great distinction. In making the award to him, he felt that the Institute had chosen a representative of what he would call "composite" British metallurgy. He had been privileged to work for 38 years in a very interesting period in the history of metallurgy.

Dr. W. H. Hatfield said that the American Institute, in desiring to honour a British metallurgist, could not have chosen any better recipient than Sir Harold Carpenter. From the standpoint of scientific metallurgy there were many things to his credit, but two were outstanding. Sir Harold's researches on the equilibrium system of iron and carbon constituted the basic knowledge of the iron-carbon system, which was still applicable. His work on single crystals was fundamental to a proper understanding of metals. On those grounds alone, from the standpoint of purely scientific metallurgy, he had completely justified the conferment of the honour upon him. Moreover, he had occupied with very great distinction the Chair of Metallurgy at the Royal School of Mines, and metallurgists in this country had elected him President of the Institution of Mining and Metallurgy, the Institute of Metals, and the Iron and Steel Institute.

Principal C. A. Edwards (Swansea) also paid tribute to Sir Harold, and said there are many things for which men strive, but as we grow older we learn how unreal so many of them are, and how ephemeral others turn out to be. All the lasting joys seemed to be those which come spontaneously, such as the honour which Sir Harold had received that day, because they are a token of the admiration and esteem in which a man is held by his fellow-men. Sir Harold can revel in an abundance of those tokens, and members of that gathering hoped he may long live to enjoy them.

Iron and Steel Institute

Annual Autumn Meeting in London

Two sessions were held for the presentation and discussion of several papers planned for reading at the cancelled New York meeting; these papers are summarised and reference made to the verbal discussion which resulted from their presentation.

THE autumn meeting of the Iron and Steel Institute, originally arranged as a joint meeting with the Institute of Metals in America for October 3 and 4 and subsequently postponed, was held at the Institution of Civil Engineers, London, on October 26; Sir Harold Carpenter, F.R.S., Past President, occupied the chair in the absence of the President, Lord Dudley, who had not then returned from America. The Chairman announced greetings and best wishes for the success of the meeting from Prof. Goerens and Dr. Petersen, on behalf of the Verein deutscher Eisenhüttenleute.

Before proceeding with the business of the meeting, the Chairman said it was his sad duty to refer to losses the Institute had sustained by death. He referred to Mr. Alfred Hutchinson, who had been a member for 43 years, and which had concluded with the Presidency; he also mentioned the recent deaths of two of the Past-Presidents of the Institute of Metals, Sir Henry Fowler and Mr. W. B. Barclay. As a token of respect the members stood in silence for a short time.

Commenting on the cancellation of the joint autumn meeting in America, Sir Harold said the programme was to have been of exceptional interest, and there was every indication of a successful meeting, but the political situation made it necessary to cancel the arrangements; the Council hoped, however, that it might be possible for a visit to take place another year. Sir Harold expressed the gratitude of the Council to the Canadian Institute of Mining and Metallurgy, the American Iron and Steel Institute, and the American Institute of Mining and Metallurgical Engineers for the work which they did in connection with the intended visit, and the deep regret which was felt at the inconvenience and disappointment which the change of plans must have caused.

Continuing, the Chairman said the Council had received an invitation to hold an additional autumn meeting in Cardiff; he believed the invitation originated from Mr. J. S. Hollings, a Vice-President of the Institute and joint managing director of Guest Keen Baldwins Iron and Steel Co. It had been arranged to hold a meeting on December 2 at Cardiff, in the building of the South Wales Institute of Engineers. The experiment of holding an additional autumn meeting in a local centre was an important innovation, because it showed the desire of the Council to provide opportunities for members to keep in touch with local developments.

TECHNICAL SESSIONS

Owing to the cancellation of the visit to America, it was not possible for some of the authors to present their papers, but Mr. D. F. Campbell agreed to present the paper on "American Electric-Furnace Practice," by Mr. W. M. Farnsworth and Mr. E. R. Johnson, in addition to his own paper on "Electric Furnaces in European Steelworks." Mr. A. R. Edwards, of the American Rolling Mill Co., presented the paper on "The Development of Continuous-Strip Mills," by Mr. D. Eppelsheimer. Mr. Quincy Bent's paper was taken as read, while the paper by Dr. C. Sykes and Mr. H. Evans was presented by Dr. Sykes. During the afternoon the Third Report of the Steel Castings Committee was presented and discussed. Brief summaries of the papers follow, together with references to the verbal discussions :—

American Electric-Furnace Practice

By W. M. FARNSWORTH and E. R. JOHNSON.

The electric furnace is used for the manufacture of many steels in the United States. Several types of electric furnace construction are in use, and of these the predominating types are the conventional Héroult arc and the high-frequency induction furnace. Low-frequency induction furnaces are few. The largest of them (6 tons) is located at the Canton Works of the Republic Steel Corporation. The Héroult arc furnaces may have either basic or acid bottoms, and generally it may be stated that the ingot-producing furnaces are basic, while the foundry furnaces for castings have acid linings. These furnaces are extremely varied in size up to 100 tons, with conventional sizes of 6, 15 and 25 tons capacity.

In the United States the arc furnaces are used for the manufacture of many grades of steel for the purpose of obtaining quality, uniformity of product, close chemistry control, special and complicated analyses. Many of the special carbon tool steels, the highest quality alloy steels, the aircraft steels, the semi and full corrosion-resistant steels, the special heat-resisting steels, the alloy tool steels, and the high-speed steels are made in the basic arc furnaces.

In this paper the authors first outline the basic electric steel furnace equipment at the Canton plant of the Republic Steel Corporation, and refer briefly to the furnace hearth construction. They then describe in detail the operation of the arc and low-frequency electric furnaces at their works, giving attention to the raw materials used and the various modes of procedure in normal alloy steel practice, stainless steel practice, arc furnace practice (with stainless scrap addition) and the duplex process for making stainless steel; logs of furnace heats are recorded. In conclusion, the authors describe the tapping and pouring procedure.

Electric Furnaces in European Steelworks

By D. F. CAMPBELL.

Technical developments vary in different parts of Europe, owing to the divergence of natural resources in different countries and their national policies of self-sufficiency. Recent developments in Europe include the construction of electric iron ore smelting furnaces of new design in the few countries where exceptional circumstances made this method of reducing iron ores commercially possible. The author refers to shaft furnaces, long used for the reduction of iron ores in Sweden, being replaced by pit furnaces of comparatively simple design, in which the rich gases are collected and used for general heating purposes. Eleven iron reduction furnaces of this new type have recently been built, of which nine are of between 6,000 and 9,000 kVA. and two are of 12,000 kVA. This industry of iron smelting in pit-type furnaces has been established in Norway, Sweden, Finland and Italy, where conditions favour electric smelting. The largest furnaces are now of 12,000 kVA., but there seems to be no reason why furnaces of very much greater power and output should not be constructed.

A large number of arc furnaces for steel-making have been constructed during the last five years in British and other European steelworks, and it is interesting to note that almost all constructors have returned to the simple three-phase furnaces with three electrodes, of which the prototype

may be considered to be the 15-ton furnace built at the Illinois Steel Co.'s works at South Chicago by that great French engineer, Paul Héroult. In Europe the number of electrodes has generally been limited to three, and there is a strong body of opinion that considers a three-electrode furnace, with a capacity of about 30–40 tons for liquid metal or 20 tons for melting cold scrap, of 8,000–10,000 kVA., as the largest unit that is convenient to operate.

The author discusses the relative merits of hydraulic and electric regulation of electrodes, fixed and removable roofs, various types of charging baskets, fixed and rotating hearths, and amorphous, graphite and Soderberg electrodes are considered, and the principal characteristics of several recent furnaces are stated. Attention is also directed to recent methods of rapid deoxidation and refining by agitation of the steel with suitable slags.

Many furnaces, the author states, still operate on the well-known methods of melting and dephosphorising with a lime/iron-ore slag at comparatively low temperatures, slagging and finishing under a white desulphurising and deoxidising slag of lime and fluorspar. Several new processes or changes in metallurgical methods of arc-furnace practive have, however, been introduced in recent years, resulting in great acceleration of the chemical reaction.

A remarkable discovery was made a few years ago—that violently oxidised metal, after the dephosphorising slag was removed, could be reduced to a properly killed steel of remarkable freedom from inclusions by rapid and violent agitation with a suitable slag free from oxide of iron. Further, it was found that sulphur could be removed by the use of an ordinary lime/iron-ore slag if the temperature was raised and precautions were taken to keep a high percentage of lime and low silicon contents in the slag. These discoveries are leading to a revolution in arc-furnace practice in some European works, and the time spent in finishing the steel after it is melted is being reduced from hours to minutes.

The question of refractories is also commented upon. The majority of furnace operators still use silica roofs for basic working, although great efforts have been made to introduce magnesia and magnesia-alumina and magnesia-chrome mixtures. Recently, an important improvement has been made in the manufacture of dolomite bricks, which can now be obtained entirely stable as regards disintegration by humidity. This makes possible the transport and storage of dolomite bricks, and it is a development of importance to those countries aiming at internal self-sufficiency, as dolomite is widely distributed, whereas magnesite deposits of suitable quality for brickmaking are comparatively rare. This development is due to a new method of preparing the dolomite, by which no free lime remains in the brick, and the results are certainly excellent as regards stability in damp weather.

It is noteworthy, in the author's opinion, that the amorphous electrode is tending to disappear, and most of the new furnaces are equipped with graphite or Soderberg electrodes. The issue between these two types of electrodes has been somewhat complicated by commercial considerations, but steelmakers who want the cheapest electrode usually adopt the Soderberg system if they have a number of large furnaces, whereas the makers of the highest grade of steel, who usually have smaller furnaces and a small number of units, use graphite.

The development of the high-frequency furnace, from the first small wooden box equipments to the modern large steel structures shielded by iron laminations or copper, is described, and typical British and Continental installations are compared. The capacity of these furnaces generally varies from 500 to 18,000 lb., and the power from 100 k.w. to 1,600 k.w. It is necessary that these furnaces shall be charged to capacity, and the size of the furnace body is therefore important. In most works, several bodies of different sizes are installed, so that small orders, experimental heats, and light castings, or larger production jobs, can be economically done with various sizes of bodies operated from the same electrical machinery.

The author proceeds to review the principal electrical features of high-frequency equipment, such as coils, condensers, motor generators, protective devices, and control gear. Typical modern high-frequency shops of British and Continental design are compared and illustrated. Finally, the possibility of using the heat and movement obtained by induction heating for refining purposes is discussed.

Discussion

Dr. T. Swinden, referring to the first paper, said he noted with special interest that in the Canton plant a 6-ton low-frequency induction furnace was in use. No information is given when this was installed, and he would like to know whether it was put in since high-frequency furnaces, of similar capacity, had been available. If so, the reasons leading to the preference for the low-frequency furnace would be interesting. Most people had ceased to operate low-frequency furnaces on account of refractory trouble, the well-known difficulty of starting up or of changing quality, and the unsuitability, compared with high-frequency furnaces, of melting cold charges, being responsible. The low-frequency furnace was not referred to in Mr. Campbell's paper on European practice, and therefore an explanation of its use at Canton would be particularly interesting.

It was clear that the authors of the American paper attached great importance to hydrogen, and they went so far as to control both the charge and the method of working on the assumption that hydrogen was an important factor in producing sound steel of the highly alloyed types referred to. Personally, however, he felt we were only on the fringe of the subject of the influence of and control of hydrogen in steel. It was possible that the figures at present recorded by the high temperature vacuum fusion method did not by any means reveal the whole story. Therefore he would like to have some actual details of the hydrogen content of the steels in question, if these could be made available.

Turning to Mr. Campbell's paper, Dr. Swinden said it was only necessary to amplify one or two points. Referring to "quick metallurgy," in connection with which a large amount of work had been done by M. Perrin, he said the fundamental soundness of the metallurgical principles involved had been established and all that remained was to determine under what practical conditions the speeding-up of metallurgical reactions could be economically achieved through the intimate mixing of metal with the appropriate slag. On the question of linings of high-frequency furnaces, it was stated that for many years acid linings had given no trouble, but there was always room for improvement. The refractory cost with acid-lined high-frequency furnaces was considerably below that of, say, a 50-ton acid open-hearth furnace. On the other hand, no really satisfactory basic lining for large high-frequency furnaces was yet available. No difficulty attached to basic linings with furnaces up to 2 tons capacity, but in the 5-ton furnaces the basic lining had not yet been produced which had the necessary refractoriness and resistance to slag attack, with freedom from shrinkage cracks, which were a potential danger to the coil.

Dr. W. H. Hatfield agreed that metallurgical considerations must dominate all these processes, but when Mr. Campbell said that a revolution was taking place in arc furnaces in European works to such an extent that the time spent in finishing the steel, after it was melted, was being reduced from hours to minutes, it seemed rather a theatrical effect to put it in that way. Prof. Perrin had made a metallurgical contribution of considerable magnitude in his ideas of bringing about chemical reactions in a very short space of time, but he had been very frank about it, and should it be found that in works usage, as distinct from the experimental field, that the process could be adequately applied, then we should have arrived at the evolution of

something of the order of a major process. For the moment, however, he would like to correct the impression conveyed by Mr. Campbell with regard to the ultimate standard of cleanliness which could be produced by the Perrin process. He had examined the Perrin product, and having regard to the broadminded manner in which M. Perrin had dealt with the matter, he rather regretted to have to say that although the standard of cleanliness was far in excess of the cleanliness achieved in what might be called the heavy steel trade, Perrin steel could only be regarded as fairly clean when compared with the arc-furnace process. Mr. Campbell had been making his comparison with the high-frequency furnace, but he had added, when presenting the paper, some words which were not in the printed version, to the effect that he was not referring to the special alloy steel trade as carried out in Sheffield, in making his comparison. That was very important, for the fact should not be overlooked that something like 90 per cent. of the total electric steel production came from Sheffield. The furnaces in all the bigger works in Sheffield were arc furnaces, and those familiar with the possibilities of the electric arc furnace process of making steel must know there was no difficulty in producing steel of a cleanliness to standards which could not be approached either by the high-frequency furnace or the Perrin process.

Mr. G. M. Brown said, in comparing the furnaces described in the two papers, it was interesting to notice the variation in the power input; in some cases smaller furnaces had the same power input as larger ones. This might be due to the fact that the furnaces were of different ages or, more probably, were used for different purposes. Mr. Campbell had mentioned graphite and carbon electrodes. Some time ago the results of an investigation were published in *Stahl und Eisen*, and the conclusion drawn was that there was very little to choose between the two from the point of view of operating cost. The Soderberg electrode, of course, was an entirely different proposition. The current density with the electrodes mentioned in the two papers varied from 75 to 95 amp./sq. in. for graphite, and from 30 to 37 amp./sq. in. for amorphous carbon, either solid or Soderberg. Apparently the Soderberg and amorphous carbon electrodes must have been very much greater in diameter than the graphite electrodes, and one would expect there would be a corresponding amount of difficulty in maintaining a good roof with an amorphous carbon or Soderberg electrode, as compared with the much smaller graphite electrodes, and a greater amount of air leakage into the furnace if the economisers and electrodes were not kept in perfect condition.

Commenting on the simultaneous control of circulation and heating, Mr. Brown referred to the very interesting furnace designed by the Swedish General Electric Co. some years ago, which was provided with both high-frequency and low-frequency supply, independently controlled. The low-frequency supply had very little effect on localised heating compared with the high-frequency, so that it was quite possible to introduce a sufficiently powerful low-frequency component into the winding of the furnace to create considerable circulation and motion of metal while still having the control of the heating effect definitely in hand.

Mr. A. Glynne Lobley commented on the sweeping statement made by Mr. Campbell with regard to electrode control. It was stated that hydraulic electrode regulators were more rapid and flexible in operation than those actuated purely electrically. Perhaps the author had compared modern hydraulic regulators with old-type electric regulators, and he was wondering whether the author had had any experience of a really modern rapid-working electric regulator. Within the past two years several firms employing a modern electric regulator, together with a fully counter-balanced electrode system, had been melting all scrap charges of stainless steel with a carbon content of 0·06% carbon and bringing out the charge with 0·06% carbon. This result could hardly be improved upon with any type of hydraulic regulator.

Continuing, Mr. Lobley said that his colleague, Mr. A. G. Robiette, who was unable to be present, had asked him to make some observations on his behalf. Mr. Robiette stated that in referring to the swivelling roof type, Mr. Campbell had made some rather vague assertions. He had referred to the ram as being attached preferably to the furnace shell. The swivelling roof was introduced in America and had since been built on this side of the Atlantic, but the ram in each case was mounted on the foundations. More recently, there had been instances of mounting the ram on the furnace body, and Mr. Robiette said he has seen both methods in operation, and could see no difference in the way the roof settled down. On the other hand, there were many disadvantages in mounting the ram on the furnace shell, such as the need for flexible hydraulic connections and the probably distortion of the furnace shell. Mr. Campbell seemed to infer that whilst the swivelling roof type was good for small sizes, the bridge type was to be preferred for large sizes. This might be the case if the ram had to be attached to the shell, but not otherwise. One of the latest, with the ram fixed to the foundations, was a 30 to 40-ton unit.

Mr. Campbell, replying, reminded Dr. Hatfield that his paper covered the whole of the electric furnace practice in Europe, and not only Sheffield. He had particularly stated with regard to inclusions that the results obtained with the Perrin process were equal to the results obtained in normal electric furnace practice. A great deal of the tonnage of steel in Europe was made in electric furnaces for comparatively common steel, and he had been referring more especially to Continental practice in making his comparison. Quite recently he had been concerned with some thirty large furnaces making basic Bessemer steel of the standard of purity, in many cases of open-hearth steel, although not the extraordinarily high standard set in the Sheffield steel works. The big variation in kVA. in different furnaces, mentioned by Mr. Brown, was a complicated subject. If a lot of steel was made it had to be sold, and the whole problem was related to the power contract. In some cities the conditions were favourable, inasmuch as one simply paid for k.w.-hours irrespective of the peak load, but that was not always the case. In reply to Mr. Lobley, he said he could not go into the argument of hydraulic versus electric regulators. They were both very good if they were modern, and personally he regarded it as a matter of choice. With regard to the observations of Mr. Robiette, he had pointed out in the paper that the swivelling roof had been used principally on small furnaces, and reference had been made to that development in Europe. At the same time, he saw no reason why larger furnaces should not be built with a swivelling roof. Indeed, there was now being built furnaces with swivelling roofs of larger capacity than any at present in operation. With regard to charging baskets, this again was very much a matter of choice. The Ford Co. had one kind, and another firm would favour another, and that, like the question of hydraulic and electric regulators, was very much a matter of personal opinion.

Specific-Heat-Temperature Curves of Commercially Pure Iron and Certain Plain Carbon Steels

By C. SYKES, PH.D., D.SC., and H. EVANS.

Recently attention has been drawn to the subject of low-temperature transformations in iron by a paper by Naeser.* From a careful series of experiments this investigator has determined a specific-heat/temperature curve of pure iron, Fig. 5 (*b*), which shows six distinct peaks, approximately 100° C. apart, between 25° C. and the A_2 point in iron. The changes in specific heat at these various transformation points are of the same order of magnitude as those occurring at the A_2 point in iron and at the Curie point in nickel. Naeser's paper is accompanied by a fairly complete bibliography of the literature dealing with low-temperature changes. This is reviewed, and it appears that some of the

*Naeser: *Mitteilungen an den Kaiser-Wilhelm Institut für Eisenforschung*, 1935, vol. 1

transformations (as fixed by Naeser's specific-heat curve) can be correlated with those reported previously from an examination of other physical properties.

The specific-heat/temperature curve, according to Naeser's investigation, appeared to be so unusual that the experiments described in the present paper, presented by Dr. Sykes, were commenced to confirm it and assist if possible in the interpretation of the low-temperature changes in iron and steel.

In this investigation measurements of the specific heat in the temperature range 80–°450 C. have been made on a number of samples of commercially pure iron and plain carbon steel. The results are in reasonable agreement with accepted values. No experimental evidence is found which confirms the presence of the discontinuities reported by Naeser and Dearden.

An examination of the published literature dealing with abnormalities in physical properties of iron indicates that the indirect evidence which this brings to the support of the work of Naeser and Dearden is not strong.

Discussion

Dr. W. H. Hatfield said this research was one of a number which had come from able collaborators of Dr. Bragg at Manchester, who, with the help of his colleagues was rendering it possible to initiate broad generalised laws which would be of great assistance to people like himself, Dr. Swinden, and others who were endeavouring to explore the possibilities of adding other elements to iron. One of the first stages in such an investigation was to clear out of the way any misunderstandings as regards the real properties of the pure basic materials used. In his own laboratories, Dr. Hatfield said that Dr. Sykes' method had been carefully examined, and as far as could be seen the only possible sources of inaccuracy which might be considered to affect the results were (1) the possible time lag between the application of heat by means of the internal heating element and the taking up of this heat by the mass of the specimens; and (2) the temperature gradient across the sample. This was not a criticism of the method, but merely a comment indicating that even the most refined method had some disability. He and his colleagues had taken very great interest in this work, and believed that Dr. Sykes had definitely established that points previously presumed to exist did not exist, which was a substantial contribution to the subject.

Prof. F. C. Thompson said he regarded the work done by the authors as being excellently designed, very faithfully carried out, and very fairly discussed. He hoped Dr. Sykes would not have any feeling that the conclusion in the paper was one which was distasteful to him. As a matter of fact, Dr. Sykes had been very fair about it, but it was a fundamental question which was at issue. The fact was that the points which the authors said did not exist had been quite independently discovered at least three times by workers who knew little or nothing of anybody else's work, and that was striking if the points had no existence at all. The points had been discovered by Borelius, of Sweden, himself and Whitehead, and by Herbert, and he regarded the matter as worthy of a great deal more research.

Dr. Ezer Griffiths said that whilst he agreed Dr. Sykes' method was not capable of giving enough specific points to enable one to sort out all these things, he felt it would be an advantage if Dr. Sykes handed samples of this steel to other people using other apparatus and methods to see what results they got. He had been astonished that Dr. Sykes and his colleague had not examined the structure of these materials at the temperatures in question, and in view of the mass of evidence that had been brought forward on the whole subject he felt justified in pressing on the authors that they should not confine themselves to one set of experiments and one piece of apparatus, but should try and study, for instance, the mechanical and other properties.

Dr. Sykes, in a brief reply, said the main thing to bear in mind was that there were changes in mechanical properties, and the problem was to find out why they existed. The experiments described in the paper were only negative evidence.

Modern Rolling Mill Practice in America

By QUINCY BENT.

This paper is a synopsis, stripped as far as possible of unnecessary details, yet touching upon the whole title, with the exception of continuous strip and sheet mills which have been purposely omitted, but an appendix is included in which separate chapters present information, more complete in detail, for the reader who has more than a casual interest in modern rolling mill practice in America. The paper describes the scientific steps taken and the methods developed for rolling steel to finished product as practised in the rolling mills of the United States. It is divided into two parts for greater convenience in presenting a comprehensive review.

It is impossible in the scope of this paper to go into a great amount of detail, but some problems are discussed which have a general interest. Attention is called to the fact that the heating of steel ingots and the semi-finished products in the rolling operation is reduced to a definite science; studies of the most adaptable types of heating furnaces adn suitable fuels are being made constantly. Application to these furnaces of instruments to control the atmospheric conditions and temperature is now the general practice.

Mention is also made in the paper that in recent years the development of rolling-mill machinery has been brought to a high degree of engineering perfection, looking towards products of more uniform qualities to meet the ever-increasing demands of the steel consumer. Rolling mills of different designs are described in a concise manner, the type of mill best adapted in its operation for rolling the different classes of product being fully explained. Contributing largely to the recent improvements and successful operation of rolling-mill machinery in America has been the development of the electric motor and its control for driving mill stands. The appendix is particularly informative, giving details in the form of data, photographs and line drawings supporting the general remarks of the author, the main sub-divisions of the subject being covered by separate chapters.

The Development of Continuous-Strip Mills

By D. EPPELSHEIMER.

This paper gives a very brief historical review of the rolling of sheets as well as of the previous unsuccessful attempts to roll sheets in continuous mills. The fundamental requirements and means for the discovery and the subsequent application of continuous-strip rolling are fully explained in detail. Particulars are given of a device for autographically recording the variations of sheet cross-section, with magnification by electrical means.

The development of the continuous sheet mill as compared with that of the Bessemer and open-hearth processes is discussed and illustrated. A diagram of the total tonnage produced by such mills compared with the production of sheets and black plates for tinning in the United States is shown for the years 1925 to 1937 inclusive. The relative productiveness of these mills regarding the men necessary and the electrical and fuel energy required is stated, and the author comments on the control of this new instrumentality to prevent dislocation of labour and injury to the sheet trade, and on what amounts to a new product in the more precise and uniform thickness of wider and larger sheets made available with improved surface and physical characteristics.

Numerous illustrations, showing a mill designed by Leonardo da Vinci up to and including the more modern four-high mills weighing 400 tons per stand without the rolls, accompany the text and make the paper both interesting and informative.

Third Report of the Steel Castings Research Commitee

IN discussing the fluidity of iron-carbon and other iron alloys, in this report of the Steel Castings Research Committee, the fluidity of alloy steels is considered for silicon, chromium, nickel and copper series, followed by considerations of the fluidity data in conjunction with the ternary sections developed. The Committee have given much consideration to the provision of a fluidity test capable of application under ordinary foundry conditions and which could serve as a reliable guide to the casting properties of steels in common use in the foundry. The Ruff fluidity test is regarded as the most promising, and is described in detail. Works results using this test are given together with fluidity-temperature relations of cast steels of various compositions, comprising both trials in an experimental high-frequency melting unit and works trials.

Although the system of plotting the fluidity values at a temperature line 50° C. above the liquidus curve has been adopted again, it is stated that a better system is to plot the temperature at which the fluidity is 12 in., against the composition, the curves derived in this manner following the liquidus curves very closely. The fact emerges that temperature is the most important factor concerning fluidity, and that composition is a relatively small factor.

The effect of heat-treatment and the mechanical properties of copper-steel castings are the subject of a short section, this revealing that very good mechanical properties may be secured in castings by the addition of copper to a variety of low-alloy steels, if the composition is carefully balanced and if suitable treatment is given.

The section on the strength and ductility of cast steel during cooling (from the liquid state in sand moulds) takes into account the influence of manganese and of sulphur, deals with high-alloy steels, the effect of rate of strain, and includes test for susceptibility to contraction cracks in horizontally cast test-bars, vertically cast test-bars, and multiple test-bar castings. This is followed, logically enough, by the first report of the Moulding Materials Sub-Committee, this comprehensive survey covering more than 110 pages, which, like the rest of the book, are well illustrated with plates, diagrams, and tabular matter.

The programme of investigation approved by the Steel Castings Research Committee covers ten main divisions: the methods of testing moulding sands for steel foundry use; continuation of Boswell's examination of possible British alternatives to French or Belgian moulding sands; the relation of the "bond" in naturally bonded and synthetically bonded sands to "stripping," "burning on," and similar considerations, also including the properties of reclaimed sand; the effect of washes and paints on stripping and the casting skin and investigation of the behaviour of special washes and paints; investigations of the behaviour of synthetic bonds with clean high-silica sand, weak clay-bonded sand, and the influence of grain characteristics on bonding; the effect of pressure on the sintering and softening of moulding sands and compos; methods for the preparation and reclamation of moulding materials; investigation of the properties of core bonds; volume changes in moulding sands and compos from 0° to 1,400° C., this including the effects of composition, grading, ramming density, and allied factors; and the effect of thermal conductivity of the mould on the casting, including experiments with moulding materials of both high and low conductivity.

This first report is a valuable addition to the literature of moulding sands, covering grading, testing, behaviour, and specific investigation work.

The concluding section of the report consists of a bibliography on the manufacture, properties, and testing of steel castings, which has been prepared by the Library and Information Department of the Iron and Steel Institute. This embraces general steel foundry practice, the manufacture of steel for castings, design and cleaning of steel castings; gates, runners and chills; moulding practice, the production of special castings, cooling phenomena and defects, heat-treatment and welding of steel castings; properties, tests, and examination of steel castings; and steel foundry plants. The latter includes plants in England, Scotland, Ireland, Canada, India, the United States, Italy, and Germany; several of the plants are those of prominent motor-vehicle manufacturers.

The afternoon session of the autumn meeting of the Iron and Steel Institute was devoted to a consideration of this report; Sir Harold Carpenter was in the chair, supported by Mr. W. B. Lake, Vice-President of the Institute of British Foundrymen. Members of the latter Institute were present at the meeting, when Mr. W. J. Dawson briefly introduced the report as a whole. The first section to be presented for discussion was the first report of the Moulding Materials Sub-Committee, which was very ably presented by Mr. W. J. Rees, and created considerable discussion. Section IV, dealing with the strength and ductility of cast steel during cooling from the liquid state in sand moulds, was presented by Mr. H. F. Hall. Mr. Martin Alexander presented Section III, on copper-steel castings, and Section II was presented by Professor J. H. Andrew, Mr. T. R. Walker, and Dr. R. J. Sarjant. There was considerable discussion on all sections introduced, in each instance the value of the report was appreciated.

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Refined Iron With Guaranteed Structure

IT is well known that chemical analysis alone is no surety of uniform results. Recent research has confirmed that the chemical composition of a pig iron does not give a complete record of its quality, foundry properties, physical characteristics, etc. Experience shows that although two irons may be of similar analysis, they can give different results in the foundry. Variations likely to arise from irons of similar analysis are being reduced by Armstrong Whitworths, of Gateshead, by guaranteeing not only the analysis, but also the structure of their refined iron.

Structure of A.W cylinder pig iron

To ensure that users of "A. W." cylinder pig iron have a true record of its quality and a complete guarantee of its uniformity, it is the future policy of the company to pour a standard test-piece from every cast of cylinder pig iron and subject this to microscopical examination. No material will be sent out unless it conforms to the structure that has proved most suitable for the particular purpose and is exactly in accordance with the customer's requirements.

Purchasers will be able to check up this modern practice for themselves, as, besides giving the exact analysis of each consignment, a photomicrograph of the material will be attached to the analysis certificate. This photomicro graph will show the iron etched at a magnification of 200 diameters.

Industrial Management and Production Control

Part II.—Raw Material, Stores and Stock

By F. L. Meyenberg

This is the second of a series of articles on the subject of industrial management and production control. It should be realised, however, that these articles cannot be expected to treat exhaustively the topics with which they are concerned, nor should they be regarded as scientific elaborations; their function is to direct the attention of readers to some general features and, as examples, to describe some practical experiences in order to survey the basic factors and to indicate the spirit in which these matters should be treated.

Material as Costing Factor

THE purpose of each industrial undertaking is the transformation of raw material by labour into saleable goods. It is obvious, therefore, that material and its economy is of essential importance to the profit and loss of the concern. Especially is that the case in metallurgical works where material forms a comparatively high percentage of the costs in contrast to mechanical engineering, for example, where labour costs have a larger influence.

In spite of this fact, it is not unusual to find the organisation of the storage of material of any kind in a state which would not be tolerated in the case of labour problems. The reason may be that the connection with money is not so obvious, and that, especially in metallurgical works, the quantities of material to be treated are so enormous, and the price per unit often so low, that waste does not seem to be essential so long as no precious metals or the loss of big quantities come into question.

This point of view, however, is wrong, and the understanding of this fact is certainly growing; the "good old times," when it did not matter whether a wagon of scrap or pig iron more or less had entered the works and was charged in the books, when even leading persons openly declared there should be one or more such wagons in excess in the works "as reserve," are definitely gone, and greater attention is given to all questions of the organisation of the storage of material.

The Purpose of Storage

The problems which arise in management of material can best be understood if the purpose of storage is clear. We can answer this question under normal conditions as follows:—

1. Only by means of adequate storage is it possible to purchase material in great quantities, from which it is drawn in many small issues, and to be sure, simultaneously, that the use remains in economic limits.

2. Only by means of storage does one succeed in having material always ready on hand when it is needed, even if longer time of delivery is necessary for the supplier.

3. Only by means of well-organised storage can a real survey of the economical situation of the works in question be obtained at any moment and a reliable calculation of costs be carried through.

The Quantities to be Stored

These three points of view—quantities, time, and costs—hardly need further explanation at first glance, but the problems are so intricate that the greatest care by the management is necessary in order to avoid mistakes, which may be detrimental for the whole concern. The difficulty is that the approach to these problems from a theoretical standpoint has proved scarcely possible. We find, especially in the American literature, many attempts in this direction, but experience has shown to me that the cases where one or the other of the nice formulas developed in the office can be used in practice are so seldom that they should better not be considered at all.

One should know that the storage of excessive quantities are connected with all the losses which follow excessive investments; that, on the other hand, stores in too small quantities bring about the danger of shortage just at the time when the material is urgently needed; and in steering between these "Scylla and Charybdis" there is, properly speaking, nothing more than "common sense" to guide. Perhaps some help can be drawn from past experience in the same works, and from the figures which can be gained by statistics of the past; but even that may be misleading in case the working conditions, especially the degree of occupation in the works, are different from that of the period in comparison. Thus the only guide which could be given generally is, perhaps, that the storage should be done with a certain margin of safety, because the disadvantages of the "too much" are smaller than those of the "too little." Further, the more the modern tendency of the continuous flow of work can be realised through the work, the smaller can and should be the storage of material.

It is no secret that a great deal of the success of Henry Ford is due to a careful consideration of this fact; and it has to be taken as a favourable circumstance that most processes in metallurgical works, ferrous as well as non-ferrous, are of this nature of continuous flow.

Another point worth mentioning is that the care in managing stores of these works should not be exaggerated to an uneconomical degree. What is meant by this remark may best be illustrated by an example: Hundreds of wagons of ore, coal, scrap, pig iron, etc., arrive daily at one of the great iron and steel works; they are driven slowly by a locomotive over a weighbridge, stopping for each individual wagon to determine the gross weight before unloading at the proper position. So far, so good; but now the empty wagons are again driven back over the weighbridge to control the tare, which is painted on each wagon. Certainly, differences will be found; they are even due to changes in the weather; but the question arises, whether the costs for the loco-service, for the men at the weighbridge, for all the clerical work connected with this procedure, etc., are not greater than the possible gain which could be obtained from reclamations because of differences in the net weight. It will be sufficient to take from time to time samples off-hand, especially when there is any reason for suspicion that something may be wrong.

The Subdivision of Material to be Stored

We have to distinguish between:—

1. Raw material which is transformed in the works by any of the manufacturing processes into goods, and is contained finally, at least to the greatest part, in these goods, termed from the costing point of view "direct material."

2. Material which is used and consumed during the production, termed "indirect material."

3. Finished material or saleable goods.

This distinction cannot be used in such a manner that the terms, as indicated above, may be allocated to a special material generally; on the contrary, they can only be used from the point of view of the works in question—i.e., what belongs in one case to one of these groups may, in another case, be part of another group; but it is necessary for costing purposes to make this distinction clear once and for all in the particular works; and where, as it occurs sometimes, a change takes place from one group to another, to provide for special measures so that correct bookkeeping takes place. In order to make these remarks perfectly clear, round bars may be goods for the works in question, and so stored in the warehouse, but for some repairs such bars are needed and have to be transferred to the "indirect material" to an extent necessary for the repair.

Special attention must be given to material which arises from the production process and is known as scrap, by-products, etc. Scrap has to be collected immediately after it has appeared and brought to the scrap dump, where it belongs, not without crediting the order or workshop, where it arises, for this return. Similarly, one has to proceed with the calculation of by-products, but here one of the most difficult questions of costing arises, which can only be solved in a special case, and even then mostly by an agreement between all concerned, because there is no solution which could be considered as absolutely correct from all points of view. It is not possible to explain this problem here in detail, as that would take more space than can be given for this whole comprehensive article.

The Arrangement of the Stores

Here, too, it will only be possible to give some general principles, as all details are to be adapted to the special nature of the material to be stored.

The question whether an *open* stockyard, accessible to everybody, or a *closed* stores or warehouse should be chosen will be decided according to bulkiness, weight and value of the material. It is clear that the latter form is the better one from an administrative point of view, as it is easier to keep the survey of what is at hand when only a limited number of persons responsible for the material has access to it. Therefore the former arrangement can be allowed only where the danger, that unauthorised people may cause disorder or remove material without orderly voucher, is excluded by the nature of material, as is the case with ore, scrap, ingots, etc. It may be expressly mentioned that these remarks are less based on the fear of loss by theft—in many cases this loss would be less than the cost of supervision of the stores—than on the fact that "open" stores make in many cases the necessary survey and bookkeeping nearly impossible.

Administration and Control

A much-discussed question is whether the proper *administration* of the stores and the *control* of the stores by suitable bookkeeping should be in one hand or strictly separated. It is clear that, in principle, only the separation can be right, because nobody's work should be controlled by himself. My experience has taught me, however, that there are cases in practice where it can be recommended to break through this principle; and here is one of these cases, where that may be advantageous. I do not speak of an irritability of the storekeeper, who may look at such a separation as a sign of distrust: that is so stupid that it does not need any regard, for there is scarcely any person in industry who has not to consent to be controlled. But the combination of proper storekeeping and bookkeeping sometimes brings about such an intimate knowledge of the requirements of the works concerned that each of these two activities alone will never produce. That, however, can be a real asset, especially in stores of great size, with perhaps thousands of various parts, where only too easily "drugs in the market" arise, which a careful and experienced storekeeper could avoid. This is certainly one of the occasions where it is evident that the persons in the works have not to be used according to its organisation, but the organisation should be built up according to the persons available. It is possible that one decides for the combination in a certain store, and this decision converts into its contrary, the separation, when the storekeeper in question retires and an adequate personality is not at hand.

If, however, the decision of separation is taken, one mistake, which unfortunately is often found, should be avoided under all circumstances—i.e., that in spite of the separated bookkeeping, beside the store, and mostly outside the store, a rump-bookkeeping is arranged in the store itself, a duplication of work which is sometimes considered an intensification of control without being so in practice. The result in this case is the enlargement of clerical work, not only by duplication but also because the two books or cards dealing with the same object must be made to coincide if a discrepancy arises. Thus it can often be observed that in addition to the bookkeeping of the stores—at present nearly exclusively carried out by card indices—the "bin cards" in the stores are continued, which contain nothing more than some of the items on the cards in the store bookkeeping, in both cases based on exactly the same vouchers. I have made good experience by suddenly scrapping these bin cards after I was sure the separated store bookkeeping was in good order. One should not reply that the storekeeper then has insufficient survey of the contents of his store; he has it by looking into the bins. But he is deprived of the possibility of artificially making the actual stock coincide with that on the bin card; thus real control by the store bookkeeping is established.

Another point of administration may be mentioned, the negligence of which often leads to trouble and sometimes of even booking the same material twice: Any purchased material should be charged to the stores and issued from the stores and not immediately charged to a special order, even if it is actually brought to the spot where it is to be used because of its bulkiness or because no other purpose of use is possible. That this strict rule ought not to be exaggerated—as no measure of organisation should be—may be illustrated by the fact that I have actually found in one case that, according to these instructions, theatre tickets for some customers, who visited the works and who should be treated politely even after business hours, have been charged and credited to stores account as "being material purchased and going inevitably through the stores."

The Stock in the Stores

It has been mentioned that the greatest attention must be given to the quantity of the "stock" in the stores—i.e., the difference between the material received and issued, or the material remaining in the stores. Attention may be drawn here only to one other detail: this stock is not always really available for any new order, because it is possible that it is already partly seized by previous orders not yet sent in shops. The bookkeeping between the "real" stock as at hand in stores and the "available" stock as free for new orders should, therefore, be distinguished. As simple as this idea is theoretically, it is sometimes difficult to carry out in practice. In any case, careful organisation, an especially close connection between the "order book," the department of production planning, and the stores bookkeeping must be made. This should be done, therefore, only where it is really necessary to avoid delays in delivery, etc.; but it is sometimes found that it is done more generally in order to avoid different forms for the two different kinds of material, the same form being used in both cases is taken by the employees concerned as an instruction to proceed equally in both cases. This remark may seem to be ridiculous, but he who knows the practice will often find that it is not superfluous to draw the attention to such incredible facts going on for years until mere chance brings them to light.

Requisitions to and Issues from the Stores

Now we come to a measure which I have heard so often indicated as "red tape," and which, I agree, must appear

at first glance to the inexperienced, mostly technically trained, mind really as red tape.

Nothing should be taken out of the stores without a regular requisition slip. How often does one hear complaints about the unnecessary " writing down on paper slips, referring to objects perhaps worth some pence," about all this work, " only invented by clerks in order to provide work for themselves and to show their own importance ! " But it must be emphasised that without carrying through this demand strictly no real survey of the economical situation of the works, no orderly bookkeeping and correct profit and loss account is possible. I know, of course, that even here exaggerations occur, but it is the " rule of large figures " which should be kept in mind, the fact that the sum of numerous small items is finally a lot, and these items easily run up in big works to many thousands a week. There is no other way than the demand of requisition slips for each item, and what makes things worse, there are many cases where the stores must deliver, for technical reasons, more than is asked for, and a return of the excess with a return slip is unconditionally needed. Naturally, the whole procedure should be made as easy for the workshops as possible, by suitable printed forms, by correct situation of and clear arrangement in the stores, etc., but that is nearly all that can be done. The fundamental demand, as already explained, cannot be abandoned.

The next stage in treating these requisition slips is the evaluating of the material, the voucher of which they are. There are in use various methods for this work :—(*a*) To take the actual value of the material, as shown by the invoice, in case the material is delivered from outside, or by calculation when produced or transformed in the works ; (*b*) to choose the " market price " ; or (*c*) to fix a " standard value " unchangeable for a certain time, perhaps the business year. I prefer personally the method under (*a*), especially because it can be reasonably explained to the employees concerned as following closest the actual course of events, but I cannot deny that the other methods have advantages, which may lead to their application—e.g., in case of great fluctuations of the market prices. I have even found, in the same works, the use of two or three of these methods simultaneously for various types of material, and had to agree that some advantages could be accomplished only in this way in the case in question. Of course, that means a more careful training and supervision of the employees concerned. But, whatever method is adopted, it should never be forgotten that, as carefully as it may be carried out, the right result can only be obtained if the original vouchers, the requisition slips, are correctly written out and correspondingly carried out, and it is here where many ridiculous mistakes often occur. The employees who have to do this work cannot, for economical reasons, be highly trained, and become easily accustomed to do their work mechanically. It is the duty of the storekeeper to supervise them continuously, and to eliminate such mistakes as using wrong lines or columns in the printed forms, by confounding the various figures, writing words or figures incorrectly, etc. These minor matters often cause trouble in an organisation, the main features of which may be absolutely sound. The planning of an organisation is comparatively easy, but it is its application in connection with all the detail work which matters in practice and decides whether the organisation is a real success or not.

There are still many other questions on storekeeping not yet treated in this article : the problems of centralisation or decentralisation of the stores, of their sub-division according to the nature of the various materials, of the position of the stores as part of the total organisation of the works, and their connection to other departments, the requirements of stores of special parts of equipment, as patterns, tools, spare parts, etc. Some of these problems will form the main subject of the next article.

(To be continued.)

Recovery of Phosphorus

THE element phosphorus continues to gain in interest and application, and, fortunately, is one which enjoys abundant reserves, there being ample supplies of phosphate rock in America, the bulk of which are in the western states, with the second largest American deposits located in Florida.

The phosphate rock as generally used for commercial purposes has an approximate phosphorus content of 14%, the usual variations being between 12 and 17%. The ore is an apatite or crystalline phosphate of lime ($Ca_{10}F_2(PO_4)_6$), and is now recovered at the mine. A large proportion is used in the relatively crude form of superphosphates in the fertiliser industry, and the application of refined compounds is comparatively small. Elemental phosphorus is mainly used for the production of phosphor copper and similar alloys.

Two methods are used for recovery, the major differences in operation being in the method of heating. In one method a blast-furnace is used, and in the other the ore is heated in electric furnaces ; both processes yield elemental phosphorus as their first product. Until recently, the phosphorus has been burnt at once, without separating it from the accompanying gases, the oxide then being dissolved in water to produce phosphoric acid, but more recent practice entails condensation of the phosphorous vapour, enabling this to be separated as a liquid. Elemental phosphorus is made in quantities by the electric furnace process, the same raw materials are, however, used in both processes.

The blast-furnace for phosphorus recovery is very similar to a blast-furnace for iron, and in the process an excess of coke is included with the furnace burden of briquetted phosphate and silica, air is blown through for combustion of the fuel, and to promote the necessary reaction by heat. Gases from the furnace vent contain a substantial proportion of nitrogen, carbon monoxide, and phosphorus vapour. Whilst hot, these gases are mixed with more air, and after burning, give off their heat content in stoves, which also are similar to those used with iron blast-furnaces ; these stoves being paired so that heat from the furnace vented gases is conserved and then passed to the air being blown into the charge. Before scrubbing of the gases, they are cooled by water spray, and their phosphorus-pentoxide content is then converted to phosphoric acid.

The distilled phosphorus obtained by the condensation process is practically free from fluorine. Phosphoric acid solutions with oxidising agents are used in the rust-proofing processes known as " Parkerising " and " Bonderising," but the main interest from a metallurgical point of view lies in the application of this element to various alloys, and new alloys of phosphorus with metals are always possible. One American authority states that recent researches have shown that phosphorus produces effects in steel quite different from those formerly credited to it but now traced to other constituents in the metal.* Regarding this from the chemist's point of view, the same writer says that the compounds of phosphorus with such common elements as oxygen, hydrogens, and the halogens involve intricacies that invite investigation. The phosphoric acids—ortho-, pyro-, meta-, and others—formed by different degrees of hydration of phosphorus-pentoxide, offer an interesting field of research. The phosphorus compounds related to phosphine (PH_3) which is a by-product of hypophosphite manufacture, and corresponding to the amines, invite investigation, particularly in view of the changes in character produced by substitution of different groups for hydrogen in the original molecule. The amphoteric character of the phosphorus atom and its two valenes of 3 and 5 suggest other values to be realised from it but as yet undiscovered.

* Ind. and. Eng. Chem. 30 : 10 : 38.

Relationship Between the Mechanical Properties and Results in Service

By L. W. Schuster, M.A.

None of the properties determined in the most commonly adopted mechanical tests is an important factor in causing a normal failure of service, stated the author in a recent lecture, under the above title, to the North-East Coast Section of the Institute of Metals; it is only in special circumstances that any direct relationship exists. The usual failure is due to faulty design or workmanship, carelessness in operation, or such causes as torsional or other form of vibration, and in this article the main features of the author's discussion are presented.

Fig. 2.—Failure of a connecting rod bolt.

METHODS of testing, suchas are called for in purchasing specifications, may be excellent in so far as they act as a check on the quality of the material, and enable the purchaser to determine that it is up to the recognised standard. I fear, however, that our standard tests, in so far as they are intended to give information that is really useful in judging the relative suitability of different materials for service, are certainly very deficient. For the most part, the methods constitute a legacy that has reached us after being handed down for several generations. They have been ingrained in us in our student days, and consequently many of us are loth to depart from them. It is only in recent years that we have started to realise how misleading may be the information given by so many forms of test. There is much that we have yet to learn, and meanwhile there is bound to be certain differences of opinion in deciding upon the most suitable material for a given mechanical part.

Tensile Tests

It was not so long ago I was advocating that a certain test should be stipulated for testing some important welded joints, when the purchaser replied that he could not understand the function of the particular test, whereas he

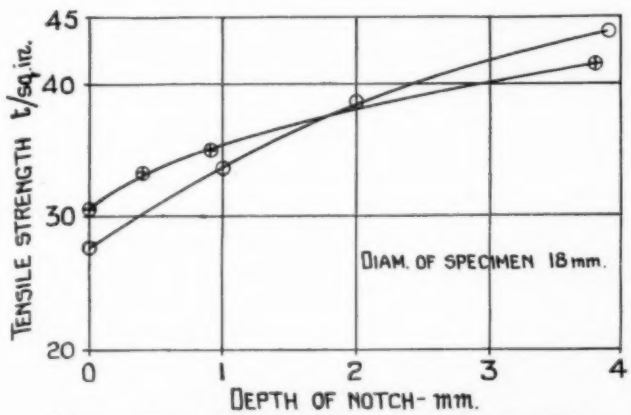


Fig. 1.—Effect of 45° V-notch in altering the tensile strength of two mild steels.

did desire a tensile test, which was a test that he could understand. He added that it served the purpose of showing the load the material would withstand before it could be pulled asunder. Unfortunately, however, a part in service is not pulled out until it fractures, as in a tensile test. Though a consequential failure may take place in this manner, a fracture in service results from a creeping crack, or a sudden rip from an initial crack, in either case without measurable distortion. The value of the tensile strength of the material, therefore, has no direct bearing on the usual failure, and though within limits it may be true that the fatigue value of a material is proportionate to the tensile strength, such an occurrence can only be looked upon as fortuitous, and any such happening was not taken into consideration when the remark I have quoted was uttered. I will refer again, later, to the fatigue test.

The tensile strength of plain machined specimens does not show the relative strength of materials under concentrated stress. If the specimen is grooved the static strength depends on the depth of the notch, and the relative strength of even two mild steels may readily become reversed as in Fig. 1.

Naturally, it is true that in a consequential failure the material may be drawn out, and an example is furnished by the connecting-rod bolt (Fig. 2). The usual occurrence when a connecting-rod bolt fails is, short of a seizure or similar mishap, for the primary failure to take place in one bolt only; a creeping crack is formed in this, and the second bolt then becomes overloaded with an eccentric load, and, consequently, is either bent or sometimes pulled out in tension, as was the bolt shown. It may be mentioned that the usual cause for the creeping crack is mal-tightening of the bolts and looseness in service, or faulty design in which the component parts are not interlocked to prevent side movement, or the bolts are not a tight fit.

Yield Point

The use of the yield-point is often recommended as a basis of design, largely with the object of making use of the greater stiffness of alloy steels. I can, however, say at once that fracturing in service of the varied class of parts of which I have had somewhat extensive experience has never—short of other defect in the material—been due to an unsatisfactory yield-point. Naturally, the measurement of the yield-point affords an excellent check in ensuring that a manufacturer is obtaining the class of steel that he has ordered or that may be necessary for a certain works' process, and knowledge of the value of the yield-point is of importance in parts such as steam turbines, having fine tolerances or small shrinkage fits, or in other parts liable to deform under particularly severe conditions of load, or in bolts that must not be allowed to become loose. Again, the yield-point is of importance in the design of columns and certain parts liable to fail by collapse.

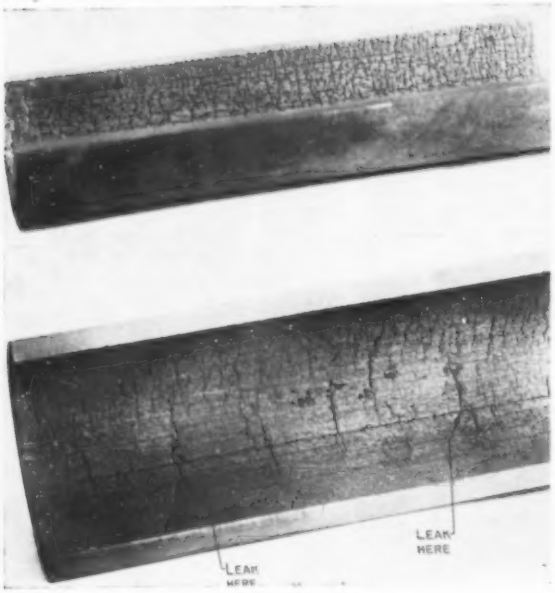


Fig. 3.—Faulty superheater tube.

Troubles arising from such considerations do not, however, constitute fracturing in service. The aim in designing a part should clearly be to ensure that the properties of the material are suitable for resisting the form of failure feared the most, and, for the general design of machine parts, the use of the yield-point as a basis is definitely wrong. Should the part work under severe conditions of shock, to raise the yield-point is just the opposite of what is required. Naturally, if a part has to work under special conditions such as are imposed by an elevated temperature, the yield-point does not increase in importance because its value does not fall for temperatures below 200° C., and for higher temperatures there is no definite yield-point. An important objection to the use of the yield-point is that for an alloy steel its value may be raised by as much as 115%, while the fatigue range is raised by only 40%. Consequently, with the yield-point used as a basis of design, the factor of safety requires to be varied for different materials, and generally a much larger factor is required for an alloy steel than for a mild steel.

It is to be realised that a low yield-point in certain parts is by no means of necessity a disadvantage, but may actually prove to be an advantage in so far as it enables a material to adjust itself to the piling up of the lines of stress at a discontinuity. As a general basis of design, the use of the yield-point is unsatisfactory if only because the measurement does not represent a fundamental property of a material, and many materials have no yield-point. A heat-treated alloy steel does not usually give a definite yield-point, such as is given by a mild steel, and the characteristic of a mild steel, which allows an appreciable strain at the yield-point without increase in stress, has certainly a distinct advantage. Again, seeing that an occasional overload may raise the yield-point of many materials without lowering the fatigue value or tending to facilitate failure, the initial yield-point has not necessarily a specific significance. Further, it may be cited that in commercial testing the accuracy of the value of the yield-point recorded on the test sheet is often open to considerable suspicion.

The use of the yield-point has been pushed to the point of absurdity, and has even been extended to riveted boilers. Seeing that it is impossible to make a rivet tight without exceeding the yield-point of the material, and that it is at the rivet holes that the breaking out of a crack is most to be expected, it is clearly irrational to base the design on the initial value of the yield-point.

As is well known, even a soft mild steel, working at the temperature of superheated steam, failing as a result of expansion and contraction stresses, does so without any noticeable change in dimension, such as occurs when a tube is overheated. Fig. 3 illustrates a superheater tube, which developed a considerable number of cracks at the bore, resulting in several punctures through the tube wall. Incidentally, the photograph illustrates the total inadequacy of commercial tests carried out on tubes; they allow material quite unsuitable for superheater tubes to pass.

Limit of Proportionality

On the question of the limit of proportionality, I do not think I need add anything to my remarks on the yield-point. A well-known metallurgist, in commenting on the making of the tensile test, said that none of the test figures recorded commercially represent fundamental properties of material, and the only fundamental property given by the test was the elastic limit, which is not usually recorded for acceptance tests. However that may be, when breakdown in service is under consideration I look upon measurement of the limit of proportionality as of even less value than the yield-point. It bears no relation to the mechanism of failure under fatigue, and any insignificant work-hardening of the material will cause its value to be altered at will. Such a basis certainly would not necessarily give benefit to a heat-treated alloy steel, as the load-extension diagram for such a material may start to tail off with zero load.

Ductility

Of the other properties of material, usually specified, ductility obtained by various methods is generally considered to be the most important, yet all of these methods miss the mark in giving information on the real characteristics of material that determine its behaviour in service. In a consideration of results, the average engineer's interpretation of the elongation measured on a tensile test is perhaps the most erroneous. The measurement undoubtedly affords a check in ensuring that a consignment of metal is up to the standard for the particular grade of material; comparison of the measured figures does not, however, afford any guide as to the relative manner in which two different grades of material will behave in service. For instance, in Fig. 4 are shown the elongations measured on different gauge lengths for two different classes of steel. If the measurement is made on the gauge length M, the one steel appears to be the better, while if the measurement is made on the gauge length N the reverse obtains. The measurement of the elongation depends upon two different characteristics of the metal, and measurement on an arbitrary gauge length is fundamentally wrong—i.e., if the object is to obtain knowledge of a particular characteristic of the material. By making measurements on a series of decreasing gauge lengths and producing the curve to the left of the diagram, we can, however, obtain a figure for elongation that is approximately related to the reduction in area of the specimen. This measurement therefore affords no information not obtainable in a simpler manner. If the curves are produced to the right, or a single measurement is made on a very large gauge length, we certainly do obtain some useful information on the capacity of the material to deform when cold-worked; the usual test-house, however, makes no profession of obtaining any such

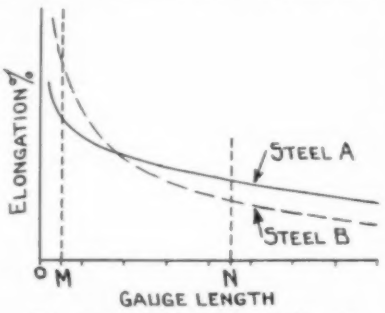


Fig. 4.—Showing the results of measuring elongations on different gauge lengths.

Fig. 5.—Surface defects in boiler plate.

figure, and at any rate the measurement has no obvious bearing on service failures. It is always to be remembered that ductility is measured after a specimen has failed, while it is obvious that that portion of the elongation, which is developed after the load has reached its maximum value, can have no influence in averting initial failure.

I think I can say without fear of contradiction that when the word "ductility" is referred to, the intention is in reality to refer to that property which is represented by the measurement of the reduction in area in a tensile test. As has been seen, the same property is obtained approximately by measuring the elongation on an infinitely small gauge length, and, as I showed in a paper a few years ago, the same property is indicated approximately when a bend specimen first fails.

The point with which we are at present concerned is, however, the relationship between this ductility and the liability to mechanical breakdown. I think we can safely say that there is no direct relationship. Though it is perfectly true that good ductility has shown itself to be an invaluable asset, that is no proof whatsoever that, if one material gives a reduction in area of 60% and another only 40%, the one giving the higher value will give better service. In fact, the reverse may readily take place. As previously pointed out, a crack spreads in a service part with no appreciable plastic deformation of the material, and the measured ductility for complete fracture is certainly not developed. A high figure for ductility can, therefore, only be looked upon as "an outward and visible sign" of a tendency towards some "inward spiritual grace."

Fig. 6.—Failure at the neck of a crankshaft; illustration shows cracks breaking out at slag threads.

Naturally, as for other test results, the measurement of the reduction in area ensures that a given material is up to standard quality.

The Bend Test

On the question of the bend test, it can be said that when this is carried out in a methodical manner the first crack will break out after a certain degree of deformation, which is approximately calculable from measurement of the reduction in area in a tensile test. The test, if made to determine ductility, is clearly redundant if the ductility of a material has already been obtained by other means. It, however, affords a cheap and rapid method of determining ductility, which can be used in lieu of other methods, or on occasions when the reduction in area is not, or cannot be, measured in a tensile test, as for flat plates or irregular sections.

The test is, however, made for additional reasons, and for material that is to be subjected to cold deformation during the later stages of manufacture it is certainly useful. In determining the suitability of material to meet the conditions of service it is often of great value, as it affords

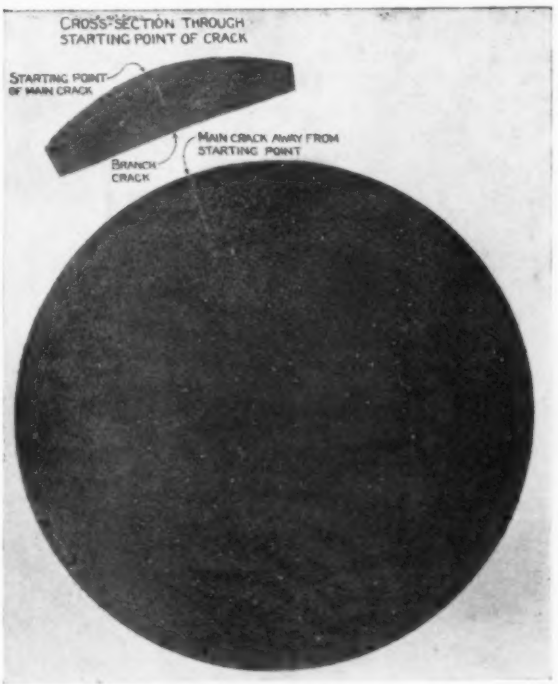

CROSS SECTION THROUGH STARTING POINT OF CRACK
STARTING POINT OF MAIN CRACK
MAIN CRACK AWAY FROM STARTING POINT
BRANCH CRACK

Fig. 7.—Cross section through crankshaft 5 in. from start of crack.

a method by which the outside surface of part can readily be tested for imperfections, and it is at the surface of the part that a crack will almost inevitably be set up in service. For example, from time to time cracks are set up in boiler plates in service, and it is traced that these have broken out at surface defects, such as are shown by Fig. 5. Similarly, it is not uncommon for failure in service to be initiated at cavities or non-metallic matter lying near the surface of the part. There is no need for me to enlarge upon the serviceability of the bend test in detecting porosity in castings or the presence of other defects. One illustration is given in Fig. 6, showing a crankshaft that developed mysterious longitudinal cracks at one of the journals—other similar cases having been experienced.

Though a longitudinal crack in a shaft may not in itself be dangerous, it frequently leads to overheating at the journal, and it is always liable to extend, when on reaching the fillet it invariably proceeds to extend in a transverse direction; the position then becomes precarious. Fig. 6 shows one of the largest of the cracks, and at the left this is turning round in a transverse direction; underneath is a smaller longitudinal crack. Fig. 7 shows that a ring of segregates coincided with the periphery of the shaft, and the inset, at the top, that the large crack had broken out along one of the drawn out segregations; it is to be noticed that

the crack, while lying in a longitudinal direction, had extended deep down into the body of the shaft. Fig. 8 shows a sulphur print round the periphery of the shaft; this makes the surface defects very evident.

Fatigue Tests

Undoubtedly, the method of applying the load in a fatigue test approaches the conditions of service more nearly than that they are initiated in any other test, even though it be not a regular works test. Clearly, however, if we assume that the fatigue range bears an approximate ratio to the ultimate strength of the material, the test fails to give information not given by knowledge of the value of this latter quality, and to make the test would serve no useful purpose. Moreover, the fatigue strength as commonly

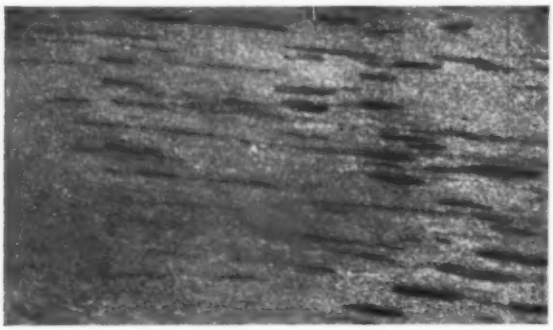


Fig. 8.—Circumferential sulphur print showing sulphide threads along the surface of the crankneck.

Fig. 9.—Circumferential cracks in crankshaft, starting at fine tool marks.

determined, is by no means of necessity a true criterion of the liability to fail under all conditions of service. If it were, we could increase the strength of materials regardless of such properties as are implied by the terms "ductility" and "toughness." Likewise, such a conception would imply that the damping properties of material are never of importance. In giving basic knowledge on the mechanism of fatigue the usual method of test does certainly serve a purpose, but experimenters are now more and more realising that the testing of machined specimens may be quite misleading for assessing the resistance against failure at the outside skin of the part represented. The outside layer of the mechanical part may be of very different quality from that in the test specimen, both in regard to decarburisation, heat-treatment, segregation, distribution of impurities, work-hardening, or other surface condition. Moreover, what the *usual* test does altogether fail to ascer-

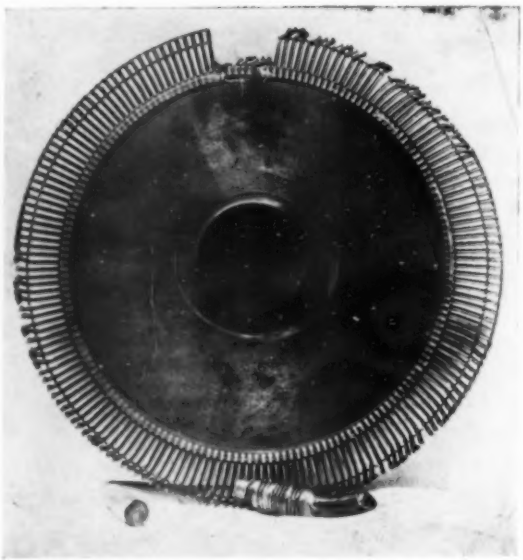


Fig. 10.—Broken turbine disc due to the presence of stamped X.

tain is the relative behaviour of materials at discontinuities, such as it is common for the part represented to contain.

As is well known, the failure under fatigue in so many instances *starts at a scratch*, a tool mark, as in Figs. 9 and 10, or a local defect, or at a discontinuity such as is caused by a fillet, a drilled hole, a keyway, or the root of a gear tooth; the information given by the usual test is therefore by no means all that is required. Moreover, the stress system in the part in service is likely to be complex, and though much effort is being made to make good the deficiency, much data is yet required on the behaviour under fluctuating stresses of materials subjected to several variations of combined stresses.

The fatigue resistance of notched bars subjected to an equal tensional and compressional stress is not necessarily the criterion determining the life of a part under all conditions of service. For example, the superposition of a unidirectional stress is able to cause an alloy steel to behave less satisfactorily than a mild steel. Another factor that may prove of importance is the ability of a given material to withstand an occasional overload, without decrease in the fatigue value, and such a property certainly assists wrought iron. Or again, this fatigue stress does not decide the behaviour of materials under impulsive loading, and for these reasons alone there must be some other property desirable in a material. I am inclined to the opinion that one of the most useful properties of material for resisting severe service conditions is its capacity for yielding without appreciable increase in the stress, and a material giving a well-marked yield-point at which there is appreciable strain, such as a mild steel, is probably the most suitable for withstanding rigorous service. From this viewpoint the ideal is that a fatigue or a bend test should be made on a notched specimen, either test being carried out up to the point of first failure, and then discontinued. Such tests, in so far as they are practicable, are able to give us information on the capacity of a material to accommodate itself to stress concentration at a discontinuity.

(*To be continued.*)

Errata

The caption to the left-hand illustration on page 192 of the October issue should read, "Steering Box," instead of "Rear Axle Housing."

The author of the article entitled "Practical Application of Hot-face Insulating Bricks," on pp. 206–8 of the October issue, is Mr. J. W. Dawson, as given in the Contents.

Institute of Metals

Annual Autumn Meeting in London

A number of papers describing some important investigations were presented and discussed at this meeting; the papers are summarised and the verbal discussion presented.

THIS annual meeting, originally arranged to be held in America jointly with the Iron and Steel Institute, and corresponding American institutes, and subsequently cancelled, was held in the Institution of Mechanical Engineers in London on October 27, with the President, Dr. C. H. Desch, F.R.S., in the chair. At the commencement of the opening meeting Dr. Desch feelingly referred to the losses the Institute and the industry had sustained recently by the death of Mr. W. R. Barclay, the immediate Past President, of Sir Henry Fowler, another Past President, and Sir Robert Mond. He also referred to the loss suffered by the sister Institute, the Iron and Steel Institute, by the death of Mr. Alfred Hutchinson, its immediate Past President.

Commenting on the cancelled American programme, Dr. Desch expressed the regret which had been felt by all concerned that it had been necessary to cancel the arrangements for the joint meeting. The decision was arrived at with the greatest regret by the officers of the two Institutes in consultation. Their American friends had expressed the hope that it would be possible to carry out something like the original programme next year, and the President hoped it would be possible to hold the meeting, so that the great efforts which had been made in America would not be wasted.

The meeting was confined to one day, comprising morning and afternoon sessions, and in consequence only a few of the papers included in the original arrangements were presented for discussion, all of which embrace work of a fundamental character on various aspects of non-ferrous metallurgy. Here it is only possible to present a summary of the papers presented, and to refer somewhat briefly to some of the discussions.

The Constitution of the Magnesium-Rich Alloys in the Systems Aluminium-Magnesium, Gallium-Magnesium, Indium-Magnesium, and Thallium-Magnesium

By WILLIAM HUME-ROTHERY, M.A., D.Sc., F.R.S., and G. V. RAYNOR, B.A., B.Sc.

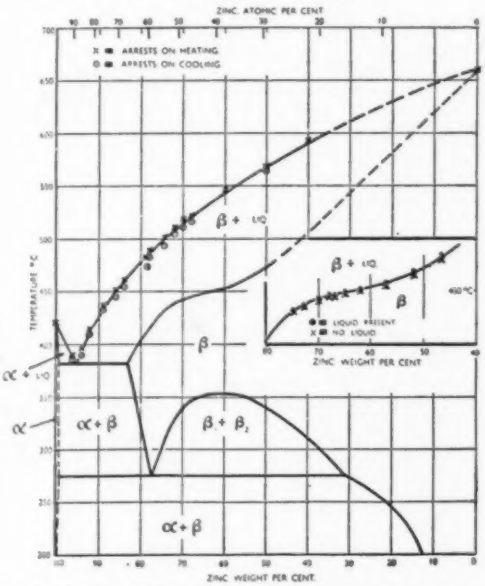
This paper, presented by Dr. Hume-Rothery, describes new experimental work, in which the equilibrium diagrams for magnesium-rich aluminium-magnesium, gallium-magnesium, indium-magnesium, and thallium-magnesium alloys have been investigated. The liquidus and solidus curves for the magnesium-rich α solid solutions were determined in all four systems, and the α solid solubility curve was determined in detail for the alloys with gallium, indium, and thallium. The liquidus curve for the system aluminium-magnesium is distinctly higher than that of previous diagrams, but agrees well with the values given by Haughton and Payne for ternary aluminium-cadmium-magnesium alloys. In the system thallium-magnesium, the solid solubility of thallium in magnesium is greater at high temperatures and smaller at low temperatures than was previously supposed, and the liquidus curve for the more concentrated alloys is higher.

A second paper by the same authors, and presented at the same time by Dr. Hume-Rothery, deals with the factors affecting the liquidus, solidus, and solid-solubility curves in the alloys considered in the above paper; the results of the investigations described in that paper are discussed from the point of view of the general theory of alloy structures. The fact that solid zinc and cadmium have a smaller tendency to form solid solutions than magnesium has is explained on the basis of the modern electron theory of metals. Of the elements of Group III B, gallium is outside the zone of favourable size-factor for magnesium, and forms a very restricted solid solution, the maximum solid solubility being 3·14 atomic % gallium. Aluminium is on the border line of favourable size-factor, and its solubility in magnesium, which is very small at low temperatures, increases to 11·5 atomic % at high temperatures, as compared with values of 19·35 atomic % indium and 15·4 atomic % thallium for the two systems where the size-factor is really favourable. Relations existing between the liquidus, solidus, and solid-solubility curves are discussed.

The Constitution of Aluminium-Zinc Alloys of High-Purity: The Nature of the Thermal Change at 443° C.

By MARIE L. V. GAYLER, D.Sc., and E. G. SUTHERLAND, B.Sc.

The object of the research described in this paper was (*a*) to determine whether or not the thermal change occurring at about 443° C. is accompanied by a phase change; and (*b*) if so, to determine the limits of the two-phase field, which, if it exists, must, according to the work of Owen and Pickup,[1] lie within very close limits—i.e., between 69·5 and 70·5% zinc, approximately.



Equilibrium diagram embodying the results of the investigation by Gayler and Sutherland, and some other investigators.

In this research the liquidus and solidus curves of high-purity aluminium-zinc alloys have been redetermined over a range of composition of 40–100% zinc by weight. The thermal analyses of alloys stirred continuously show definitely that: (*a*) the heat-change which occurs on heating takes place over a range of temperature and not at constant temperature; (*b*) the temperature at which maximum heat-absorption occurs falls with increasing zinc content; and (*c*) on cooling, a heat-evolution occurs at very nearly constant temperature.

Microscopic analysis shows: (*a*) no primary separation along the liquidus between the melting point of aluminium and that of the eutectic, other than that of the aluminium solid solution; (*b*) no evidence of the existence of a two-phase field above 360° C.; and (*c*) no evidence of a "reaction" compound.

1 E. A. Owen and L. Pickup. *Phil. Mag.* 1935 [vii], 20, 761.

The heat-change which occurs over the range of temperature 440°–470° C., has been shown to be due to a marked change—of about 12% zinc by weight—in the composition of the primary aluminium phase which takes place during solidification over a very small temperature interval, approximately 12° C. A revised equilibrium diagram is given, which embodies the results of the present investigation and of several previous investigators, and is reproduced in the accompanying illustration.

Copper-Rich Nickel-Aluminium-Copper Alloys Part II.—The Constitution of the Copper-Nickel-Rich Alloys

By W. O. ALEXANDER, B.Sc., PH.D.

Previous work and Part I of the present investigation[2] have shown that copper-nickel alloys containing aluminium are susceptible to hardening by heat-treatment. The object of the work described in the present paper, presented by the author, was to determine the phase changes which are involved in this hardening of the alloys.

In this research a series of aluminium-copper-nickel alloys containing from 1 to 35% aluminium was made, and the phase changes which these ternary alloys undergo on heat-treatment were studied by thermal analysis, and by micrographic and X-ray methods. The phase relations at the solidus and at elevated temperatures are shown to be: (1) primary separation of the compound NiAl containing copper in solid solution; (2) NiAl is isomorphous with the β phase (Cu_3Al) at elevated temperatures, but immiscibility occurs below 750° C.; (3) a eutectic valley runs from the nickel-aluminium to the copper-aluminium binary alloys, the liquid initially separating $\alpha + \theta$ (Ni_3Al) and, below 1,250° C., $\alpha +$ NiAl (isomorphous with β). Thus, at low temperatures two phases of the nickel-aluminium binary system, namely the compounds NiAl and θ (Ni_3Al), are shown to take some copper into solid solution, and in these forms—i.e., as NiAl solid solution and θ (Ni_3Al) solid solution, to extend their phase-formation influence right into the copper corner of the ternary diagram to compositions of the order of only 3% nickel, with 3% and 1% aluminium, respectively.

The Tarnishing of Silver and Silver Alloys and its Prevention

By L. E. PRICE, M.A., PH.D., and G. J. THOMAS, B.Sc., PH.D.

The discolouration which occurs when silver is exposed to an atmosphere contaminated with sulphur compounds constitutes the main disadvantage to the use of this metal. In this paper is described an investigation as a result of which the authors advance theories leading to the development of oxidation treatments which render silver alloys containing either aluminium or beryllium uniformly and highly resistant to tarnishing. Prof. R. S. Hutton presented this paper on behalf of the authors and emphasised that the work described was due to support given by the Worshipful Company of Goldsmiths.

In the investigation 70,000 specimens of pure silver and of 100 of its alloys were exposed for periods up to one year in 15 different locations, mainly in living-rooms and kitchens. The tarnishing of these specimens was followed by the observation of the tarnish colours produced, and by an electrometric method. Although previous investigators have shown that oxide films may retard tarnishing, hitherto it has not been possible to explain why some oxides have a particularly high protective effect against oxidation or tarnishing. A theory has been developed which shows the factors involved in tarnish-resistance. This has explained many previous results, and has indicated that other alloys (e.g., those containing aluminium) which have not previously been found to be tarnish-resistant, become tarnish-resistant when the alloy is heated under such conditions that only the aluminium is oxidised, giving rise to an invisible film of pure alumina. Tarnish-resistant films cannot be formed by heating these alloys in air, owing to the fact that both the silver and its alloy constituents oxidise simultaneously. Optimum results can only be expected with pure films of such oxides as alumina or beryllia, when free from silver oxide.

Two methods were developed for the formation of such films of pure alumina or beryllia: (1) Selective oxidation of aluminium or beryllium in silver alloys by heating in hydrogen containing 0·1 mm. partial pressure of water vapour, to give a film of pure alumina or beryllia; and (2) superimposing transparent, cathodically deposited films of these oxides on pure silver and its alloys. Such oxide films are found to be highly protective against tarnishing.

Oxidation-Resistance in Copper Alloys

By L. E. PRICE, M.A., PH.D., and G. J. THOMAS, B.Sc., PH.D.

Although a large amount of work has been carried out on heat-resisting alloys, few principles have emerged to guide the choice of alloying elements. In the first part of this paper, the authors have made some attempt to correlate, qualitatively at least, the effect of adding various elements to copper, with the latest theories concerning film formation. It is shown, from theoretical considerations, that an alloying constituent added to prevent high-temperature oxidation should have a sufficient affinity for oxygen, and should on heating form an oxide film of high electrical resistance. If possible, the radii of the cations in the protective oxide should be small, and the oxide must not be one which is deficient in cations. These principles provided an explanation of the good resistance to oxidation conferred on copper by additions of beryllium and aluminium, and suggested a method by which it could be increased.

By pre-treatment of aluminium-copper alloys in suitable atmospheres, continuous films of pure alumina were formed on the surface, which resulted in increased resistance to oxidation.

In presenting this paper on behalf of the authors, Dr. U. R. Evans said that although we would not reap the fruits of the authors' results for some years, at any rate until the various practical difficulties had been overcome, those results were very encouraging. He did not think that the position indicated in the paper would have been reached but for the fact that the authors had carried out their work under scientific conditions, studying the reasons for the effects of the various alloy constituents, and choosing each step by the aid of the theories arrived at; they were able to choose each step so that they obtained progressively better results.

Discussion

Mr. A. R. Powell substantiated all the claims made for the beneficial effect of the oxide film obtained by the authors' heating process, when that film was produced on flat surfaces which could be heated in an easily controlled atmosphere; but he pointed out that the difficulties became much more pronounced when heating large articles, especially those with hollow parts, in a commercial furnace. For work on an industrial scale it would be necessary to do very much more extensive investigation, especially from the point of view of determining the scratch resistance. The opinion of himself and his colleagues was that the filming operation would be extremely valuable for articles which were chiefly of ornamental value, rather than articles which were used continuously in the kitchen or dining-room; it would be almost impossible to clean off the remains of food from utilitarian articles without spoiling the film.

Expressing his interest in the theories of preferential oxidation as a means of protecting silver and copper against tarnishing, Mr. Powell asked whether the authors had tried to find out how long the film produced by electrolysis on pure silver would stand when exposed to alternating dry and damp atmospheres. It seemed to him rather too much to hope that a material such as beryllium oxide, or aluminium oxide or hydroxide should remain adherent to a pure polished silver surface. One could understand an

2 W. O. Alexander and D. Hanson. *J. Inst. Metals*. 1937, 61, 83.

oxide film, such as alumina, adhering to a pure aluminium surface, because surface atoms of aluminium had been converted into oxide by the electrolytic action. But in the other case, one was depositing cathodically, presumably by a secondary reaction, a film of oxide on a metal which was quite dissimilar, and he found it rather difficult to envisage a proper keying effect between the oxide film and the silver.

Discussing the practical aspects of the second paper, Dr. W. H. J. Vernon said the authors had shown that, in the presence of suitable alloying elements, heat-treatment under very low partial pressures of oxygen would bring about the selective oxidation of the alloying constituent, with the formation of a tenacious film. That was obviously a discovery of the greatest importance, and he admitted frankly that in his own early work in that field he had completely overlooked that factor of the use of low partial pressures of oxygen. He had tried the effect of heating aluminium-brass in air at various temperatures from the point of view of subsequent resistance to tarnishing, but negative results were obtained in every case. The authors of the papers, however, had shown that the preliminary oxidation must be conducted under higher specialised conditions, and everyone interested in the subject must be grateful to them for having established those conditions.

He and his colleagues at Teddington, however, were not so happy about the theoretical position. The authors had adopted whole-heartedly the view of Wagner. In effect, that theory provided an alternative to the ordinary thermal diffusion of oxygen through the film, and it facilitated the very helpful conception of the diffusion of metal ions through the oxide film, which was put forward by Pfeil, but in that view the electrical conductivity of the surface film was the prime factor, and one gathered that it was almost the only factor to be taken into consideration, although there were other factors involved which might in certain cases take control.

Discussing the tarnishing of silver, Dr. Vernon said it was unfortunate that the authors' experiments seemed to have been made with emeried specimens, because silverware was not normally used in that condition; differences in behaviour might result from differences in surface conditions, and he exhibited a diagram indicating that there was greater loss of reflectivity when surfaces were polished than when emeried. He disagreed profoundly with the authors' conclusion that accelerated tarnishing tests were not reliable. Their conclusion was based on tests on specimens in the upper part of a 200 c.c. flask containing 50 c.c. of $\frac{1}{10}$ saturated hydrogen sulphide solution, and in the upper part of a 200 c.c. flask containing 50 c.c. of $\frac{1}{10}$ saturated hydrogen sulphide solution containing 0·5 c.c. of 0·880 ammonia per litre. Such experiments could not be expected to give reliable results, and there was no need to disturb one's faith in the reliability of properly conducted tarnishing tests as the result of conclusions based on such experiments.

With regard to the erratic results obtained by the authors on silver-beryllium alloys and their theory that the results depended on the relative degree of humidity at the time the specimens were first exposed (there being a high resistance to tarnish if the humidity was right and a low resistance if the humidity was wrong), Dr. H. A. Sloman commented that there were no figures in the paper indicating the desirable humidity. The implication seemed to be that in his own experiments he was extraordinarily lucky, and that every time he exposed a specimen some kindly providence was at hand to ensure that the humidity was correct, so that the results were consistent. A far more reasonable explanation would be that the alloys were subject to intense segregation and showed a tendency to coarse structures; both those conditions would lead to erratic results.

The pre-treatment of the specimens in a low pressure of oxygen was undoubtedly a great step forward, and he congratulated the authors on having brought forward that fact. He had never claimed that untreated beryllium-silver alloys were definitely untarnishable; but they had a very high resistance, and the pre-heating was just what was wanted to make them completely immune from tarnishing. Finally, he asked what degree of resistance to scratching was afforded by the films, and whether the cathodically deposited films had any colour as distinct from the colour in the alloys on which they were superimposed.

Mr. A. W. Hothersall asked whether the authors had identified the cathodically deposited oxide film as consisting of the hydroxide of aluminium or beryllium, as they had suggested. The process, if practically successful, should be very important and should have a very wide application, but it was a little regrettable that there was not more information to confirm the claims made as to the nature of the film. For example, he imagined it would be easy to confirm the nature of the films, since it should be fairly easy to colour by depositing it in the presence of a dye dissolved in the solution.

Mr. W. Freeman Horn said he had gathered from someone in the silver trade that the production of non-tarnishing silver was only half the problem. A more difficult matter was to persuade people to buy the material when produced, because if it did not tarnish they would not buy it, because they did not believe that it was silver. Another consideration was that the real beauty of silver was apparent only after the silver had been subjected to continual cleaning, and any connoisseur of silver could at sight tell the difference between old and new silver.

Professor F. C. Thompson expressed admiration for what he regarded as a very beautiful piece of pure scientific work by the authors, and he congratulated them as well as those who were responsible for the supervision of the department in which it was done.

Professor Hutton, who said it was only fair that the authors should have the opportunity to reply when they returned to this country, excused them for not having put so much detail of past work into the paper as they might have done. He knew that they felt very strongly their debt to past workers, and if they had not referred to past work as fully as they would have liked, it was due to the necessity for keeping the papers reasonably short, rather than to any lack of appreciation. Commenting on Dr. Vernon's remarks, he said that most of the specimens used were not emeried.

Some Characteristics of Copper-Aluminium Alloys Made from Aluminium of Very High Purity

By Dr. MARIE L. V. GAYLER.

The use of high-purity aluminium for studying the ageing of 4% copper-aluminium alloy coincided with the obtaining of anomalous results, which could only be attributed to the quality of the aluminium used, and irregularities became accentuated to a marked degree. This paper describes the preliminary results and the experiments carried out to overcome these irregularities; the varieties of aluminium used are designated "Super Purity" French aluminium, 99·99%; Hoope's aluminium, 99·96%; and commercial aluminium, 99·6%.

Dr. Gayler states that it is extremely difficult to obtain a 4% copper-aluminium alloy made with super-pure French aluminium in such a condition that it will age-harden uniformly to the maximum extent at room temperature. Hot-working, followed by solution heat-treatment at 500° C., results in little or no age-hardening at room temperature. The microscopic examination of such material shows segregated areas of fine particles of $CuAl_2$, which alone would be sufficient to account for non-uniform results. The most satisfactory results were obtained on an alloy of 1 in. diameter section, by cold-forging with a fairly light blow on all faces, down to $\frac{1}{2}$ in. square section, and then on one face down to the required thickness.

It is suggested that the lack of homogeneity in the age-hardening of these alloys is due to the fact that: (*a*) the alloy is not easily work-hardened, owing to the aluminium matrix being plastically deformed without appreciable

work-hardening, probably on account of partial self-annealing during working; and (*b*) the particles of $CuAl_2$ act in a manner similar to that of the hard particles in a bearing metal and are, consequently, little deformed except under special conditions.

A comparison is made between the characteristics of alloys made with Hoopes' metal and with aluminium of super-purity. High-purity copper-aluminium alloys do not supercool. The macro- and micro-structures of the normally cast alloys are similar to those of commercial alloys which have been supercooled. A brief examination has been carried out of the effect of added impurities on the grain growth of recrystallised aluminium. It is suggested that the fine grain-size of the 4% copper alloy containing iron, is due to the mechanical prevention of grain growth by the presence of the insoluble iron-rich constituent in the grain boundaries.

Discussion

Professor D. Hanson recalled some experiments he had made in which he had prepared a series of aluminium alloys containing all the elements likely to occur in Duralumin (copper, magnesium, etc.), singly or two or three together. The specimens were heated to 500° C., quenched and allowed to age, and he had measured hardness in order to find out which substances were likely to be responsible for age-hardening. The aluminium which contained copper showed no appreciable age-hardening at ordinary temperature; it was made with the commercial aluminium of the time and was lightly forged to give a slight flattening of the surface to enable Brinell hardness measurements to be made. Magnesium gave the greatest hardening. He was quite satisfied that there were conditions under which copper-aluminium alloys did not age-harden readily at room temperatures. In the course of some work by Dr. Gayler and himself on aluminium-copper alloys, it was found that the age-hardening was not very great, but other workers had found much greater degrees of age-hardening. He wondered whether the amount of working which Dr. Gayler and himself had applied to their specimens was so slight that the composition of the alloy was not reasonably uniform. A certain amount of cold working did aid in evening up composition on annealing. In his own experiments the hardness results were very erratic, and possibly the fact that the amount of cold working was so slight, together with heterogeneity of the alloys, was largely responsible for that. If some had low copper content and others had high copper content, the spread of the copper contents might be very considerable if the annealing did not result in homogeneity; the slight age-hardening that might occur might easily be hidden by the spread of the Brinell hardness results.

The explanation that it was due to the absence of appreciable work-hardening during the deformation of the metal was not satisfactory to him, because he could not find anything in the paper to link up the absence of cold working with the absence of age-hardening after subsequent heat-treatment.

Dr. H. Sutton, after expressing appreciation of the author's experiments and the very careful way in which they had been recorded, said that they might lead to something very valuable, from the practical point of view. He recalled that some years ago he had come across a forging which would not age-harden. The structure of the forging was rather similar to that of some of the samples the author had illustrated in the paper. In that connection, he said it was well known by technologists that Duralumin could be over-worked, and that the resistance to age-hardening was generally less after rather severe hot working. He asked whether Dr. Gayler held the view that the ground mass was so soft that in deformation the particles were not broken up.

The President said the suggested explanation that the highly purified aluminium was so soft that it flowed over the particles was not at all unreasonable. It was remarkable how greatly the hardness of aluminium was affected by minute quantities of impurity. The results had been published of some French work in which a careful comparison was made between different specimens of highly purified aluminium, the purity of which differed minutely, and the diminution of hardness as the maximum purity was approached was very remarkable indeed.

A very remarkable fact, of which it was extremely difficult to find an explanation, was that an alloy containing pure aluminium and a large percentage of copper was markedly different in structure from an alloy of similar composition made with commercial aluminium. The difference was rather like that between an under-cooled and a non-under-cooled alloy; but under-cooling was not observed, and it was difficult to find a reason for that marked difference. It seemed hardly to be accounted for by the minute quantity of impurities present in the one case. That was a very interesting point which had come out clearly in the author's figures.

Dr. Gayler, replying to the discussion, suggested that perhaps Professor Hanson had not quite understood her point that the absence of age-hardening was not associated with cold working, but with hot working; in all the earlier work that was done, including that in which she was associated with him, the alloys were hot worked at 450°. None of the alloys she had used were found to work-harden, and that was due, she believed, to the flow of the aluminium during the forging process; if there were any work-hardening, recrystallisation occurred immediately, and there was excessive grain growth. Whilst agreeing with Professor Hanson that the lack of homogeneity in the hot-forged alloys was due to $CuAl_2$ not going into complete solution, she doubted that that was the reason in the case of the cold-worked alloys which had shown age-hardening. Another explanation which she had put forward tentatively, but which she had not yet had time to study carefully, was that the alloys had very big grains and the Brinell hardness impression in some cases could quite well go into one grain.

The Effect of Small Additions of Tellurium on the Mechanical Properties of Pure Tin

By Prof. D. HANSON, D.Sc., and W. T. PELL-WALPOLE, B.Sc., PH.D.

The preparation of tin-rich tellurium-tin alloys is described in this paper, and typical microstructures are given. It is shown that there is a small solid solubility of tellurium in tin. Additions of 0·05 to 1·0% tellurium produce a slight progressive increase in the Brinell hardness and tensile strength of pure tin as chill-cast, as chill-cast and annealed, as cold-rolled, and when annealed after cold-rolling. The effect of cold rolling and subsequent ageing on the Brinell hardness of these alloys has been studied, and it is shown that they work-harden to a remarkable degree compared with other tin-rich alloys. Ingots which had been annealed before the deformation tests, work-hardened to a much less extent, and it is suggested that grain-size and the removal of the cored structure are the cause of this weakening.

It is suggested that short-time tests, which indicate the capacity for work-hardening, may be valuable as a guide to the relative creep strength of alloys; this is confirmed in the present work. It is shown that tellurium has a very beneficial effect on the creep strength of pure tin. The alloys are strongest in the chill-cast state, slightly weaker when rolled and self-annealed, and much weaker when annealed at a high temperature either in the form of ingots or rolled material. It is noted that the grain-size of the annealed specimens has a very marked effect on the creep strength, confirming observations of Hanson and Sandford[1] when working with other tin-rich alloys. Further work on the creep-strength of these alloys, particularly with regard to the effect of grain-size, is now in progress.

1 D. Hanson and E. J. Sandford. *J. Inst. Metals*. 1938, 62, 215.

Iron Ore in the Urals

By A Special Correspondent

The iron resources of the Urals are discussed and proposals suggested for their development. The possibilities are very great, and it is considered that, with the employment of modern metallurgical technique, the resources of the Urals can add much to the industrial development of the U.S.S.R.

THE remains of ancient ore workings found in the Urals testify that metallurgy was known there in olden times. Inhabitants of Novgorod who penetrated to the Urals in the 9th century were known to have remarked on these old workings. The Urals set out on the road of industrial development in 1701, and for the space of more than a hundred years afterwards produced more pig iron (by several times) than France, Prussia and Belgium. Pig iron from the Urals used to be exported to Europe, where it enjoyed a high reputation. For two hundred years Ural factories supplied Russia with the majority of the products made from her iron mines.

The feudal Urals employed serf labour and adapted the whole of her industry—organisation, distribution, size and equipment of enterprises—to this system. Hence she was unable to withstand the competition of technically equipped foreign capital which had created a powerful metallurgical industry in the south ; in 1885 the production of pig iron in the Urals was 660,000 tons, and in the south 120,000 tons ; later the position was reversed : in 1913 the Urals produced 1·8 million tons and the south 6·39 million tons. At the outset of development in the Krivoi Rog district the quantity of ore raised in the Urals exceeded by five times and more that raised in the Krivoi Rog. But in 1913 the quantity raised in the Urals was only 26% of that produced in the Krivoi Rog, and they were faced with the prospect of decline.

Construction on a planned basis brought about a revival of the natural resources of the Urals and led to a greater knowledge of these resources. In 1910 the iron ore reserves in the Urals were thought to be no more than 282 million tons ; in 1936 the reserves were estimated at 1,625 million tons. As a result of the development of the various regions of the U.S.S.R. and the creation of a coal-metallurgical centre in the East, the raising of iron ore in the Urals was greatly increased. In 1936 the quantity raised was 7·3 million tons, constituting 42% of the quantity produced in the Krivoi Rog. This big forward jump in the raising of iron ore, however, was only in respect of the Magnitnaya deposit. In other deposits of the Urals the increase in production was not so considerable, representing only some 5 or 6%. A number of mines were shut down and ore raising was concentrated in the remaining mines.

Ural iron ore was until recently regarded only from the angle of its iron content and the presence in it of harmful admixtures. Yet Ural ore is rich in useful admixtures, which are a great advantage to Ural iron, and which for hundreds of years was famed for its ductility, malleability, and resistability to rust. At present, with the production of iron in the U.S.S.R. on a mass scale, the question has arisen of developing the production of high quality steel in the Urals. Side by side with the powerful works producing base metals on a mass scale, it is proposed to create a number of enterprises for the output of narrowly specialised metals using as a base the compound iron ores containing useful admixtures of manganese, chromium, titanium, vanadium, etc., to meet the greater demands of Soviet industry. Though required in comparatively small quantities, it is imperative that these requirements should be met. For this purpose it is proposed to erect small but modern melting and rolling plants, which would use ores of specific quality from the various deposits of the Urals. To some extent Soviet industry has already embarked on this course. Several works in the Urals (the Chusovsky, Minyarsky, Beloretsk) are engaged in specialised smelting and rolling.

The Urals possess about 190 small and big deposits of iron ore. The registered reserves of each of these deposits ranges from 100,000 to 100 million tons (not counting the deposit of Magnitogorsk). The raising of ore on a large scale can only be organised in the bigger deposits, but with a proper approach, mechanical methods of raising can also be applied to the smaller ones. Situated in groups, the deposits in the Urals can be jointly worked. In the Alapayevsk district, for instance, within a radius of one to three kilometres are nine deposits with reserves aggregating 143 million tons. The Zyrian group includes seven deposits, with reserves aggregating 38·2 million tons within a radius of two kilometres.

There has been a controversy as to whether to smelt the ores of the numerous deposits in the Urals in big or small plants. But the view is gaining ground that large-scale metallurgical production should be combined with more modest specialised concerns using the small deposits and working on local fuel. On the basis of the big reserves (Komarovo-Zigazinsk, Khalilovo, Bakal), big works should and must be built. But the building of any one of these would require an additional stream of coal coming along the already congested route—from the Kuznetsk basin and Karaganda. At the same time, however, the ore supplies of the Urals permit the expansion of the production of quality metal without any need to overload the transport system. Hence, side by side with the building of big works, it is proposed to construct comparatively small enterprises for the utilisation of the numerous deposits of iron ore containing valuable admixtures.

The iron ores of Alapayevsk may be instanced. These ores contain the following admixtures : Manganese, titanium, tin, lead, chrome, cobalt, nickel and copper. The content of each of these admixtures in the ore is small, but in the aggregate they constitute a perceptible quantity ranging in broad limits from 0·01 to 1·3% (not including the admixture of copper). The admixtures enumerated testify to the complex character of the ore. Each useful admixture separately, perhaps, would not exercise a perceptible influence on the quality of the iron, but taken together they undoubtedly ennoble the metal.

Unfortunately the distribution of useful admixtures in the iron ore of the Urals has been insufficiently studied. In existing printed summaries only two or three indications of the presence of chrome, nickel, cobalt, tin, lead and other valuable admixtures in the ore can be found. It is proposed, therefore, that Soviet metallurgy should utilise the high quality ores not for the smelting of simple standard metal, but for the production of specialised pig iron ennobled by useful admixtures ; this will involve considerable investigatory work to determine the degree of regularity in the composition which can be maintained.

Useful admixtures in the ores are found in different combinations, and the ore deposits are distributed in different regions of the Urals. Hence a more rational utilisation of the ores can be attained in specialised small-scale factories. The idea is to link up the creation of these factories with the development of charcoal smelting of iron ores. It has long been known that charcoal-smelted pig iron possesses higher mechanical properties than coke-smelted pig iron. Most of the deposits of iron ore in the

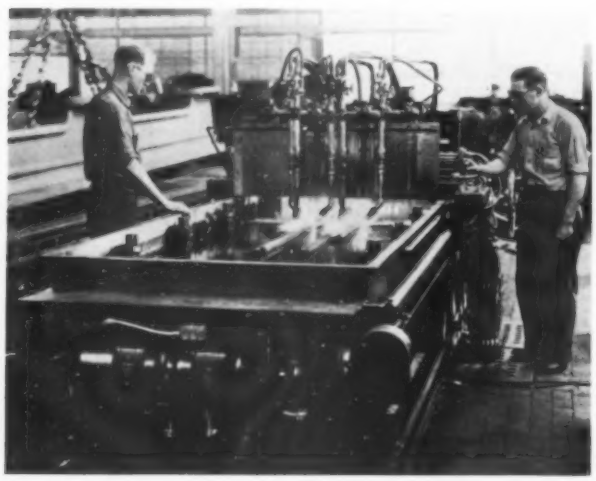
Urals are situated in forest zones or in districts adjacent to big forests. The reserves of timber available for carbonisation in the Sverdlovsk district alone are estimated at 1,108 million cubic metres; in addition, are the Chelyabinsk district and the Bashkirian Republic, which have reserves of more than 200 million cubic metres. To this must be added the annual growth. When it is remembered that the total consumption of timber in charcoal-burning at present does not exceed 10 million cubic metres, it will be seen what great reserves of fuel for ferrous metallurgy the Urals possess.

Charcoal smelting requires small furnaces (no more than 100–200 cubic metres in volume). This makes it possible to utilise the more valuable deposits even in spite of their being so scattered and small. At the same time, by a rational organisation and distribution of charcoal-burning, it can be done without exhausting the forest resources. The development of charcoal metallurgy and the opening up of new mines is bound to make industrialisation in the Urals more equal. This will enhance the importance of the Urals as an industrial centre, possessing skilled personnel, sufficient housing, and a comparatively developed local community.

Great possibilities for an extensive utilisation of the iron ore base in the Urals is opened up by Vorkutinsk coal. According to provisional data, this coal is suitable for coking and reserves of it are considerable. Its utilisation will not create additional congestion on the transport system of the Urals.

Moreover, it is also proposed to use the waterways (in addition to the railways) to bring the ore to the factories and to export the manufactured and semi-manufactured products to other places. Many of the old factories were situated on the rivers: the Chermozsky, Dobryansky, Pozhevsky, Nytvensky, and other factories were on the Kama; the Maikorsky on the Inva, the Chusovsky, Utkinsky, Revdinsky on the Chusovaya, the Kutimsky on the Vishera. Cheap water transport will considerably extend the radius of economic relations of each industrial undertaking, factory or mine. Even shallow rivers, such as the Sylva, Yaiva, Kolva, Vishera, and others can be utilised.

Metallurgy in the Urals has vast possibilities for further development. Supported by a high technique, the natural resources of the Urals can be made to give much to the industrial development of the U.S.S.R.



In the October issue reference was made to the heat-treatment of lathe beds by means of flame hardening equipment; the above illustration shows flame hardening equipment used in this method of heat-treatment.

The wide range of Birlec electric furnaces is detailed in a new folder issued by Birmingham Electric Furnaces, Ltd., a range that is possibly not realised in full by all furnace users. The company are making a policy of issuing circulars or similar literature giving practical data on typical electric furnace applications.

The Training of a Metallurgist

CONSIDERABLE interest was shown in an open discussion at a recent meeting of the Midland Metallurgical Societies on the above subject. The discussion was opened by Mr. W. F. Brazener, who, speaking as an industrialist, pointed out that metallurgists were developed either by starting in a works laboratory after leaving school, or by taking a university course. As to which type of training produces the most efficient metallurgist, the answer appears to be that ultimate success depends more on individual qualities than on the type of training received, but having gained sufficient knowledge, by whatever method, to enable the young man to call himself a metallurgist, the real training of the metallurgist will then begin. One of the most profitable training grounds in industry is in the investigation of complaints, as the fundamentals of metals and alloys become deeply embedded in the mind by such investigations.

Speaking from the research standpoint, Dr. Brownsdon said that training could be divided into two categories—that provided by tuition and that provided by oneself. The first was merely a kind of mass production, but the training he wished to draw attention to was the art of thinking. A little knowledge with the ability to apply it was more valuable than a lot of knowledge without that ability. One of the main foundations of good training was to make it broad, and the metallurgist must become inspired by the work of those scientists which had gone before. He should know what they had done and why they had done it. Industrial development must be followed in exactly the same way. The birth and development of new industries should be a lesson and should be studied. New ideas must be born and thought about, even if it was found that they had been anticipated.

Metallurgical study in a university, Professor Hanson pointed out, endeavoured to give the student a knowledge of the nature of metals and alloys and of the processes by which they were obtained from the ore and prepared for use by man. This involved a knowledge of chemistry and physics, and metallurgy was in fact the application of chemistry and physics, including mechanics, to the study of metals and their utilisation. The primary object of a university course in metallurgy, therefore, was to turn the student into a good chemist and physicist. Since, however, the practice of metallurgy involved doing things on a commercial scale, a knowledge of the applied sciences was also necessary, together with some training in business principles. The student should also learn to do things.

Dr. J. C. Hudson considered that insufficient attention was paid to the knowledge of modern languages. A university graduate should be equipped to continue his own training, and this could not be done by any man with a limited knowledge of languages. If in his searching for information the only language available was English he was severely handicapped. The opinion was expressed by Mr. Fletcher that the universities tried to make a student not so much a metallurgist as a "Jack of all trades;" if he was rightly taught about the peculiarities of alloys he had little time to study anything more.

On the Continent, Mr. Bamford pointed out, it was common practice for one year to be spent in a works, but during that time the pupil was still considered to be a student on the register of his college. While the universities gave excellent opportunities, he thought a technical college, coupled with works' training, opened up very good opportunities for the metallurgist. The real problem was how to get them trained sufficiently well, said Dr. Johnson; it was all a question of time, and it had to take time. There was always prejudice between the academic and practical sides, but if a man could see industrial problems in the academic light, or vice versa, he was in a better position than the man who absorbed academic training only.

Others contributing to the discussion included Messrs. Thomas, Richards, Llewellyn, Mort, Jones, Lewis, Bucknall, Fraser, and Capt. Parkes.

Business Notes and News

Air Mail and Christmas

This will be the first Christmas when the Empire Air Mail scheme is in operation to 40 countries, including Africa, India, Australia, and the Far East, and Imperial Airways, Ltd., is called upon to transport in five weeks a weight of mail several times greater than the whole year's external air mail of any other single country. As readers are aware, this scheme, whereby all first-class mails are carried by Imperial Airways without surcharge, has already set this country far ahead of any other in air mail transport. During the next few weeks, however, this scheme will be severely tested, and Britain's civil aviation will be faced with a unique challenge in dealing with Christmas mails of unprecedented dimensions.

This task will be greater than any air transport company has been called upon to accomplish, and business houses and individuals are asked to make their packages for overseas as light as possible, and to adopt any means of reducing the amount of mail to be sent by air during the period mentioned. Business firms can help in many ways which need not be stated here, and of course they are helping themselves by making it easier for the scheme to operate with the maximum efficiency.

Some Recent New Zealand Contracts

A number of contracts, valued at £179,000, has, we understand, been placed with British firms on behalf of the New Zealand Government Departments. The largest order is one for two water turbine generator sets, valued at about £80,000. Other contracts have also been placed for steel plates, train lighting equipment, steel bars and tubes, copper wire, lifting grabs, and steel billets. The contracts follow an order recently placed with the North British Locomotive Co. for locomotives to the value of approximately £340,000, and bring the total contracts placed by the New Zealand Government in Great Britain in the last few weeks valued at more than £500,000.

New Development at Ford Works

A recent development in the foundry at Ford Works, Dagenham, is the introduction of an extensive scheme of mechanical charging of the cupolas by telpher machines. The charge for a cupola, consisting of various proportions of pig iron, steel scrap, coke, and limestone, is usually collected in barrows and charged by hand, but by the telpher system now employed at Ford Works the whole of the work is done mechanically.

Empty charging skips are carried along a monorail track into the pig field, where the requisite amount of pig iron and steel scrap is dropped into them from hoppers, in which it has previously been weighed. The hoppers themselves are loaded by magnet and gantry cranes, and their contents are discharged through pneumatically operated doors. From the pig field the skips are automatically rolled on to a chain conveyer, which carries them beneath two large hoppers for a further charge of coke and limestone, also previously weighed. Finally, the overhead telpher charging machine picks up the skips and carries them right into the cupolas. A "wishbone" or "yolk" inside the cupola causes the bottom of the skip to open, and allows the charge to be spread over the inside of the furnace.

Chemical Engineering Show at Frankfurt

The date when the Achema IX, Chemical Engineering Show, organised by the Dechema, German Society for Chemical Engineering, will be held at Frankfurt a.M., has now been definitely fixed. It will take place from June 28 to July 7, 1940, on the occasion of the general meeting of German Chemists and of the second International Chemical Engineering Congress, which is also held at the same time in Germany.

AGENTS

Representation of Lancashire and Yorkshire areas wanted by progressive firm, well known in the Metallurgical industries. British or foreign firms should write in the first instance to Box 147, c/o METALLURGIA, 21, Albion Street, Gaythorn, Manchester 1.

"Berengaria" for Breaking-up at Jarrow

Sir John Jarvis has been successful in securing the Cunard White Star liner *Berengaria* for breaking up at a price which is stated to exceed £100,000. It has been known for some time that Sir John, in pursuance of his policy to provide more work for Jarrow unemployed, was endeavouring to buy the *Berengaria* and bring it to Jarrow, as he brought the *Olympic*. It is stated that a new company, the Jarrow Shipbreaking Co., is to be formed in time for the arrival of this vessel, which will arrive at Jarrow early in the New Year.

The *Berengaria*, which was built at Hamburg in 1912 and was formerly the German liner *Imperator*, is one of the largest ships afloat. She is of 52,000 tons gross, and will provide employment for about 200 men for a couple of years or so.

Automatic Control of Blooming Mill

Results of the automatic control installed for experimental purposes in a blooming mill at the Makeyevka Iron and Steel Works in the Donets Basin were recently considered at a meeting of the Commission on Mechanics and Automatic Processes of the Academy of Sciences of the U.S.S.R. Attended also by representatives of the industry, the meeting worked out standard methods for operating mills equipped with this control, which considerably increases productivity. Extensive use is made of the photo-electric cell in the control equipment, which was designed at the Stalin Electrical Machinery Works in Kharkov. The control enables the position of the ingot in the mill to be changed automatically.

Coke Oven Managers' Association

The above association held its annual dinner at the Hotel Victoria, London, on October 27, under the presidency of Mr. J. Curry, at which were present over 250 members and guests, including the Rt. Hon. Sir Thomas Inskip, C.B.E., M.P., who in proposing the toast of the Association, stressed the importance of the coking and by-products industry to the country in times of peace and war. Mr. Curry, in responding, said that although the Association was not very large its members were enthusiastic in their efforts to extend the industry. Some 25 million tons of coal were carbonised yearly —one-tenth of the total coal raised—about 70 million gallons of light oils were recovered, equivalent to 40 million gallons of rectified benzol. Toluol was not very important in peace time, but the coking industry was ready when the Government called for production.

The toast, "Our Guests," was proposed by Mr. D. R. Wattleworth, and replied to by Mr. G. Dixon and Mr. H. Haswell Peile; and Mr. G. W. J. Bradley proposed the toast, "The President," which Mr. Curry acknowledged.

International Nickel Co. of Canada, Ltd.

A net profit of $7,552,123·15, equivalent to 48 cents per share on the common stock, after allowing for preferred dividend, is reported for the third quarter of 1938, in the quarterly statement of the International Nickel Co. of Canada, Ltd. This compares with a net profit of $6,618,486·47 for the previous quarter, which was equal to 42 cents per share on the common. Net profit for the first nine months of 1938 was $24,284,374·31, as compared with $38,944,380·30 for the similar period in 1937, or $1·56 per share, as against $2·57 a year ago. The consolidated balance-sheet of September 30 shows current assets at $78,963,931·35, including $39,584,573·67 in cash. These figures compare with current assets of $85,509,082·58, including $48,871,395·90 in cash, as of December 31, 1937. Earned surplus as of September 30 was $71,917,359·10, as compared with $70,950,662·36 at the beginning of the year.

In a letter to shareholders, Robert C. Stanley, Chairman and President, calls attention to the major use of nickel as an alloying element, and explains what alloys are and why they are used. At present there are more than 8,000 standard alloys, of which some 2,300 contain nickel, using approximately 75% of the 200,000,000 lb. of nickel the company produced last year.

Four-high Reversing Mill for Poland

W. H. A. Robertson and Co., Ltd., recently shipped to Poland one of their many four-high reversing mills, for installation in the works of an important firm in the Katowice district. This mill is a noteworthy example of the Robertson rolling mill, and is designed for cold rolling steel strip 1 metre wide in heavy coils of 2,200 lb., finishing down to a thickness of 0·3 mm. The mill is driven by a reversing motor of 900 h.p., giving a variable rolling speed of 0–120 metres per minute.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£100	0	0

ANTIMONY.

English		£71	0	0
Chinese		56	0	0
Crude		38	10	0

BRASS.

Solid Drawn Tubes	lb.	0	1	0
Brazed Tubes	,,	0	1	2
Rods Drawn	,,	0	0	9½
Wire	,,	0	0	8½
*Extruded Brass Bars	,,	0	0	5½

COPPER.

Standard Cash		£46	12	6
Electrolytic		53	0	0
Best Selected		51	10	0
Tough		51	0	0
Sheets		84	0	0
Wire Bars		52	15	0
Ingot Bars		52	15	0
Solid Drawn Tubes	lb.	0	1	1¼
Brazed Tubes	,,	0	1	1¼

FERRO ALLOYS.

‡Tungsten Metal ° Powder, nominal	lb.	£0	4	9½
‡Ferro Tungsten ° nominal	,,	0	4	8
Ferro Molybdenum °				
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL: 2–4% Carbon, scale 12/– per unit	ton	34	15	0
NOMINAL: 4–6% Carbon, scale 8/– per unit	,,	24	5	0
NOMINAL: 6–8 Carbon, scale 7/6 per unit	,,	24	0	0
NOMINAL: 8–10% Carbon, scale 7/6 per unit	,,	24	0	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit	,,	37	0	0
Guar. max. 1% Carbon, scale 13/– per unit	,,	39	0	0
§Guar. max. 0.5% Carbon, scale 13/– per unit	,,	49	0	0
‡Manganese Metal 97–98% Mn	lb.	0	1	3
‡Metallic Chromium	,,	0	2	6
§Ferro-Vanadium 25–50%	,,	0	14	0
§Spiegel, 18–20%	ton	11	0	0
Ferro Silicon—				
Basis 10%, scale 3/– per unit nominal	ton	10	5	0
20/30% basis 25%, scale 3/6 per unit	,,	12	0	0
45/50% basis 45%, scale 5/– per unit	,,	12	10	0
70/80% basis 75%, scale 7/– per unit	,,	17	0	0
90/95% basis 90%, scale 10/– per unit	,,	30	0	0
§Silico Manganese 65/75% Mn, basis 65% Mn	,,	18	15	0
§Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20–25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	5

FUELS.

Foundry Coke—				
S. Wales	—	2	0	0
Scotland	—	1	15	0
Durham	—	1	14	6
Furnace Coke—				
Scotland	—	1	10	0
S. Wales	—	1	7	6
Durham	—	1	7	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£67	0	0
*Commercial Ingots		51	10	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0	11
*Cored Bars	,,	0	1	1

MANUFACTURED IRON.

Scotland—			
Crown Bars	£13	10	0
N.E. Coast—			
Rivets	12	15	0
Best Bars	15	15	0
Common Bars	12	10	0
Lancashire—			
Crown Bars	13	10	0
Hoops	14	2	6
Midlands—			
Crown Bars	13	10	0
Marked Bars	15	15	0
Unmarked Bars		—	
Nut and Bolt Bars	11	15	0
Gas Strip	14	2	6
S. Yorks.—			
Best Bars	15	15	0
Hoops	14	2	6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	£0	0	11
*Cored Bars	,,	0	1	1
†Strip	,,	0	0	11¾
†Sheet to 10 W.G.	,,	0	1	0½
†Wire	,,	0	1	1¾
†Rods	,,	0	1	1¾
†Tubes	,,	0	1	7
†Castings	,,	0	1	3

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £32 above English Ingots.

PIG IRON.

Scotland—			
Hæmatite M/Nos.	£6	13	0
Foundry No. 1	6	0	6
,, No. 3	5	18	0
N.E. Coast—			
Hæmatite No. 1	6	13	0
Foundry No. 1	5	11	6
,, No. 3	5	9	0
,, No. 4	5	8	0
Silicon Iron		—	
Forge	5	8	0
Midlands—			
N. Staffs. Forge No. 4	5	8	0
,, Foundry No. 3	5	11	0
Northants—			
Foundry No. 1	5	11	6
Forge No. 4	5	5	6
Foundry No. 3	5	8	6
Derbyshire Forge	5	10	0
,, Foundry No. 1	5	14	0
,, Foundry No. 3	5	11	0
West Coast Hæmatite	7	4	8
East ,, ,,	7	3	6

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Export pig-iron, maximum percentage of sulphur 0·015, of phosphorus 0·025.	
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Per metric ton	Kr.335-385
Per English ton	£17 11 3/£20 3 9
Wire Rods, over 0·45 Carbon.	
Per metric ton	Kr.375-405
Per English ton	£19 12 2/£21 4 9
Rolled Martin Iron, basis price.	
Per metric ton	Kr.230-250
Per English ton	£12 1 2/£13 2 2
Rolled charcoal iron, finished bars, basis price.	
Per metric ton	Kr.360
Per English ton f.o.b. Gothenburg.	£18 17 6

SCRAP METAL.

Copper, Clean	£34	0	0
,, Braziery	31	0	0
,, Wire		—	
Brass	20	10	0
Gun Metal	34	0	0
Zinc	8	10	0
Aluminium Cuttings	59	0	0
Lead	14	0	0
Heavy Steel—			
S. Wales	3	10	0
Scotland	3	6	0
Cleveland	3	7	0
Cast Iron—			
Midlands	3	5	0
S. Wales	3	10	0
Cleveland	3	10	0
Steel Turnings—			
Cleveland	2	13	0
Midlands	2	5	0
Cast Iron Borings—			
Cleveland		—	
Scotland	2	2	6

SPELTER.

G.O.B. Official		—	
Hard	£11	0	0
English	15	17	6
India	15	0	0
Re-melted	13	0	0

STEEL.

Ship, Bridge, and Tank Plates.			
Scotland	£11	10	0
North-East Coast	11	10	0
Midlands	11	10	0
Boiler Plates (Land) Scotland	12	0	0
,, ,, (Marine) ,,		—	
,, ,, (Land), N.E.Coast	12	0	0
,, ,, (Marine) ,,		—	
Angles, Scotland	11	0	6
,, North-East Coast	11	0	6
,, Midlands	11	0	6
Joists	11	6	0
Heavy Rails	10	2	6
Fishplates	14	2	6
Light Rails	10	7	6
Sheffield—			
Siemens Acid Billets	11	15	0
Hard Basic £6 17 6 to	10	2	6
Medium Basic, £6 12 6 and	10	0	0
Soft Basic	8	15	0
Hoops	11	15	0
Manchester Hoops	11	5	0
Scotland, Sheets 24 B.G.	15	15	0

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Round and Squares, ¼ in. to ½ in.	,,	0	0	3
Under ½ in. to ⅛ in.	,,	0	1	0
Round and Squares, 3 in.	,,	0	0	4
Flats under 1 in. × ¼ in.	,,	0	0	3
,, ,, ½ in. × ¼ in.	,,	0	1	0

TIN.

Standard Cash	£212	10	0
English	212	10	0
Australian		—	
Eastern	218	0	0
Tin Plates I.C. 20 × 14 box	1	0	3

ZINC.

English Sheets	£29	10	0
Rods	17	0	0
Battery Plates		—	
Boiler Plates		—	

LEAD.

Soft Foreign	£16	9	0
English	18	0	0

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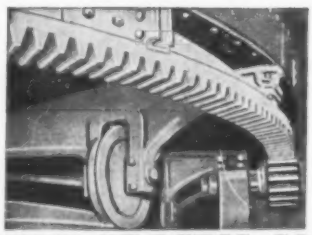

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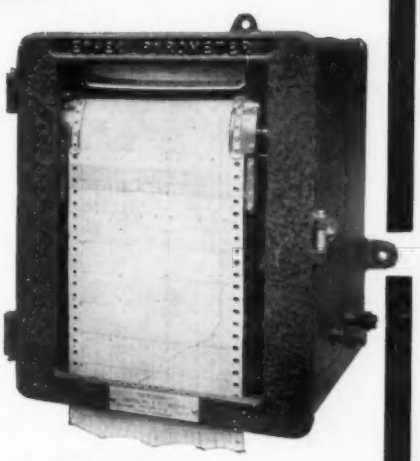

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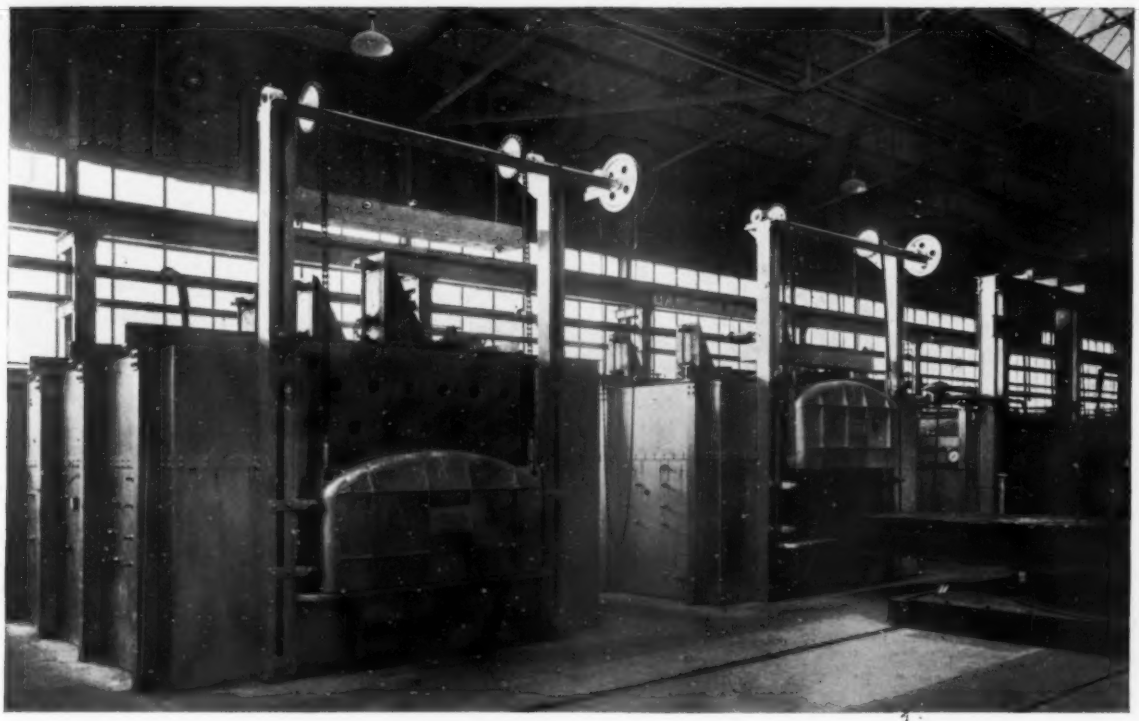

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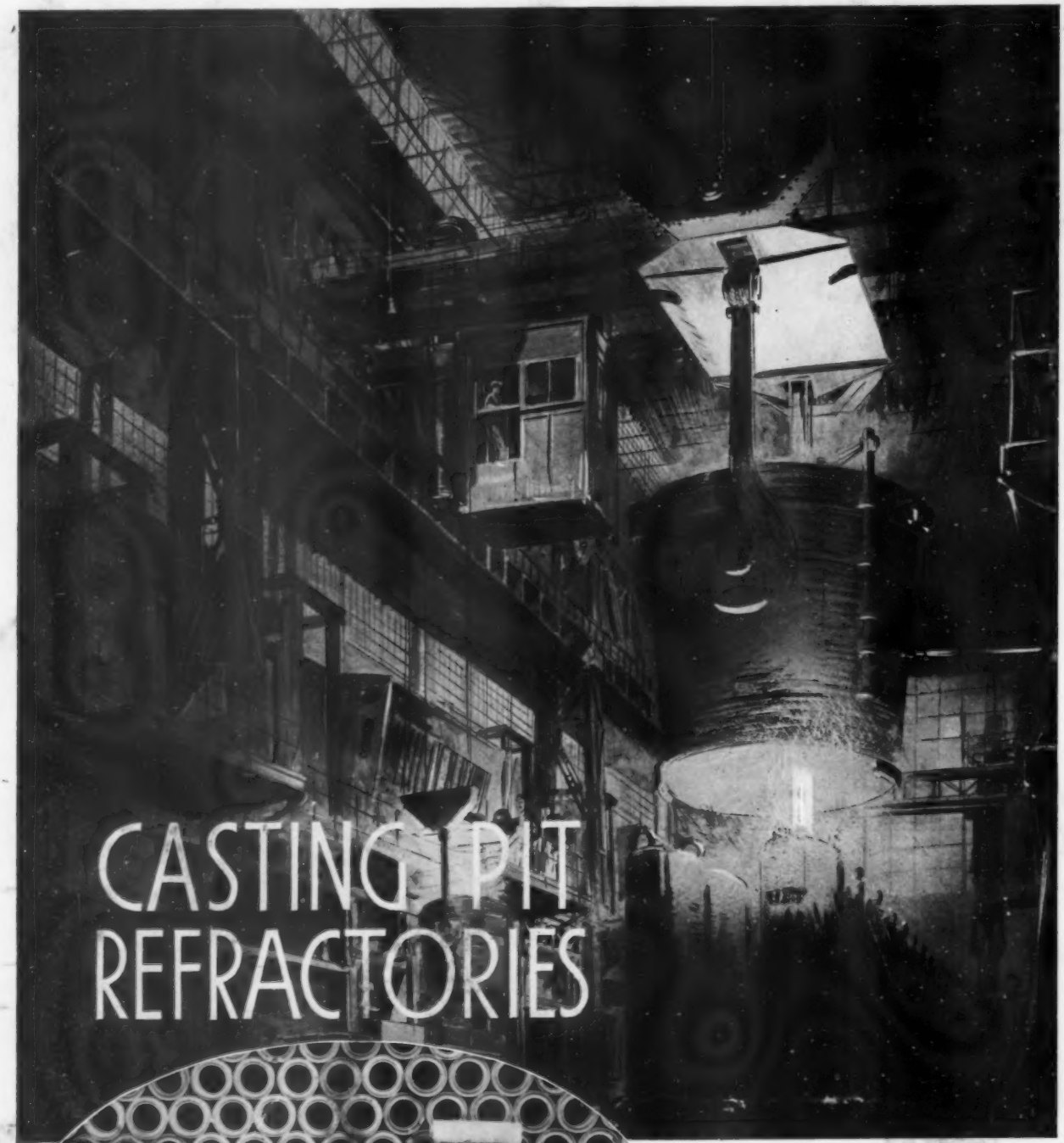

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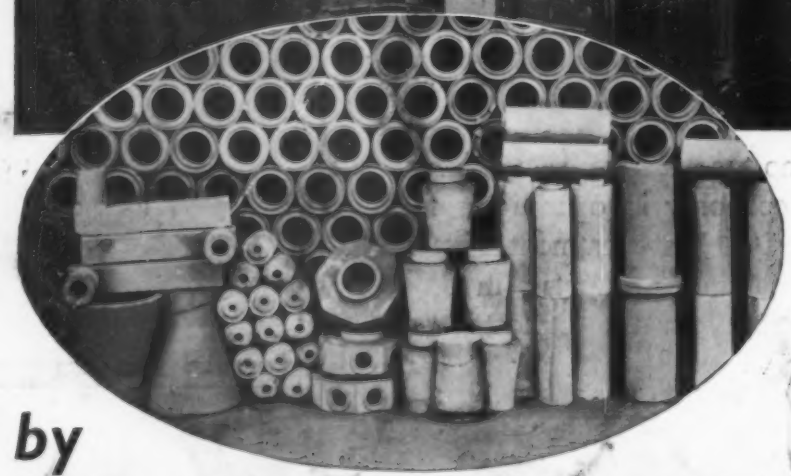

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